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IRRIGATION FARMING IN SOUTHERN ALBERTA

by

K. W. Hill and A. E. Palmer

EXPERIMENTAL STATION
LETHBRIDGE, ALBERTA



Plastic siphon tubes provide uniform streams to individual furrows of row crops.

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PREFACE

The irrigated section of southern Alberta bids fair to become one of the most stable agricultural areas of Western Canada. Organized irrigation began in 1901 and experience over the past fifty years has established that a wide variety of profitable crops can be grown here in abundance. The limited summer rainfall and prolonged periods of warm weather, so destructive to crops under dry farm agriculture, have proved advantageous to irrigation farming. The practice of feedlot finishing of livestock on irrigated farms is increasing, thus providing the ideal outlet for many farm products and agricultural by-products and at the same time conserving or increasing the general farm fertility.

The purpose of this bulletin is to review the common agricultural practices in the area and to present information which may assist in the stabilization of agriculture in this and similar areas. The experimental results, suggestions, and recommendations contained in the following pages do not arise solely from work at the Lethbridge Experimental Station; experience and data from other Canadian and American institutions have been drawn upon freely as have suggestions from many farmers and associates. The present and proposed expansion in irrigated land on the prairies will require a large increase in the number of irrigation farmers and it is hoped that this bulletin will prove helpful to them.

Since earliest settlement southern Alberta has been largely a wheat-producing area and considerable wheat is still produced on irrigated lands. However, progress toward stable farm economy has been made only as more specialized and more profitable crops have been introduced, and their culture adapted to local conditions, and as livestock production has become more general. When farming practices are intensified the native fertility of the soil often is reduced. To maintain high fertility and at the same time produce a profitable sequence of crops is the task of both the farmer and the agricultural scientist.

TABLE OF CONTENTS

	PAGE
Introduction.....	7
Climate.....	7
Altitude.....	7
Temperature.....	8
Precipitation.....	8
Evaporation.....	9
Sunshine.....	10
Wind.....	11
Soil.....	11
Drainage.....	13
Methods of Irrigating.....	13
Ditches and Dams.....	13
Wild Flooding.....	13
Flooding from Contour Ditches.....	15
Border Dike or Border Ditch Flooding.....	15
Furrows and Corrugations.....	17
Siphon Tubes and other Control Devices.....	17
Sprinkler Irrigation Methods.....	17
Points to Remember in Irrigating.....	18
Some Irrigation Terms.....	18
Crops grown under irrigation.....	19
Alfalfa.....	19
Seed-bed preparation.....	19
Method of Seeding.....	19
Rate of Seeding.....	19
Irrigation.....	19
Methods of Handling.....	20
Bacterial Wilt.....	20
Alfalfa Varieties.....	20
Alfalfa as a Soil Improving Crop.....	21
Fertilization.....	22
Alfalfa and Weed Control.....	23
The Place of Alfalfa in the Rotation.....	23
Alfalfa Seed Production.....	23
Sugar Beets.....	24
Choice of Land.....	24
Seed-Bed Preparation.....	24
Varieties of Seed.....	26
Types of Seed.....	26
Whole Seed.....	26
Decorticated Seed.....	26
Single Germ Seed.....	26
Date of Seeding.....	26
Rate of Seeding.....	27
Methods of Seeding.....	27
Replanting.....	27
Hand Thinning.....	27
Pre-thinning Weed Control.....	27
Implements for Pre-thinning Weed Control.....	28
Spike Tooth Harrow.....	28
Finger Weeder.....	28
Side Delivery Rake.....	29
Rotary Weeders.....	29
Estimating the Stand.....	29
Mechanical Thinning.....	29
Cross Blocking with Beet Cultivator.....	30
Dixie Cotton Chopper.....	30
Eversman (Soucie) Blocker.....	30
Silver Thinner.....	30
Recommendations for Mechanical Thinning.....	30

	PAGE
Crops grown under irrigation— <i>Concluded</i>	
Sugar Beets— <i>Concluded</i>	
Cultivation.....	30
Commercial Fertilizer for Sugar Beets.....	31
Manure for Sugar Beets.....	31
Irrigation.....	31
Harvesting.....	31
Potatoes.....	32
Choice of Land.....	32
Seed-Bed Preparation.....	32
Planting.....	33
Fertilization.....	33
Cultivation.....	33
Irrigation.....	34
When should Potatoes be Irrigated.....	34
Method and Amount of Irrigation.....	34
Harvesting.....	34
The Cereal Grains.....	35
Cultural Practices.....	35
Irrigation.....	35
Green Manure Crops.....	35
Sweet Clover.....	36
Other Green Manure Crops.....	36
Irrigated Pastures.....	36
Choice of Land.....	36
Pasture Mixtures.....	37
Seed-Bed Preparation.....	37
Nurse Crop versus No Nurse Crop.....	37
Seeding.....	38
Pasture Management.....	38
Irrigation.....	38
Canning Peas.....	38
Choice of Land.....	38
Seed-Bed Preparation.....	38
Seed and seeding.....	38
Fertilization.....	39
Irrigation.....	39
Harvesting.....	39
Preservation of Pea Vines.....	40
Place of Peas in the Rotation.....	40
Canning Corn.....	40
Choice of Land.....	40
Seed-Bed Preparation.....	40
Time of Planting.....	40
Seed and Seeding.....	41
Cultivation and Weed Control.....	41
Irrigation.....	41
Harvesting.....	41
Sweet Corn Stover for Fodder.....	41
After Harvest Treatment of Corn Land.....	41
Beans.....	42
Pumpkin.....	42
Other Specialty Crops.....	42
Crop Rotation.....	42
The Ideal Crop Rotation.....	42
Planned Cropping Program.....	44
Sequence of Crops and Field Arrangement.....	44

	PAGE
The Place of Livestock on the Irrigated Farm.....	49
Manure.....	50
Importance of Liquid Manure.....	50
Amount of Bedding.....	50
Care and Preservation.....	50
Application of Manure.....	52
Methods.....	52
Rates.....	52
Time to Apply.....	52
Residual Effect of Manure.....	53
Crops that Respond to Manure.....	53
Reinforcement of Manure.....	54
Value of Manure.....	54
Commercial Fertilizers.....	55
Commercial Fertilizers are only Supplementary.....	55
Distinct Need for Phosphate Fertilizers on Irrigated Prairie Soils.....	56
Potash Supply in Prairie Soils.....	56
Soil Drifting Control on Irrigated Land.....	56
Prevention of Winter Drifting on Exposed Crop Land.....	56
Prevention of Drifting on Partial Summerfallow.....	56
Emergency Control Methods.....	57
Cover Crops.....	58
Control of Drifting Immediately after Seeding.....	58
Weed Control.....	59
Annual Weeds.....	59
Control by Culture.....	59
Control by Chemicals.....	59
Perennial Weeds.....	59
Control by Culture.....	59
Control by Chemicals.....	59
Planning for Permanence and Balance in the Farming Enterprise.....	60
Preservation of Fertility.....	60
Balance Sheet of Farm Fertility.....	60
A Balanced Labour Program on the Irrigated Farm.....	62
Summary.....	63

IRRIGATION FARMING IN SOUTHERN ALBERTA

K. W. Hill¹ and A. E. Palmer²

INTRODUCTION

A half century has elapsed since organized irrigation began in Alberta. In 1907 the Dominion Experimental Station was established at Lethbridge and for over 40 years investigations into irrigated farm practices and dry-land culture have been conducted there. The present irrigated area in Alberta consisting of slightly more than 500,000 acres comprises less than three per cent of the improved arable land of the province but this acreage produces almost ten per cent of the gross farm revenue. Plans have been made to put another 1,000,000 acres "under the ditch" in the immediate future, and dams and canals now are under construction to provide water for 350,000 acres of this total.

Early experience with irrigation in Alberta was discouraging. Farmers did not wish to use water or pay for the service in years of higher rainfall. At peak demand in the drier years the supply facilities were inadequate. Wheat was raised as the cash crop and the increased yield as the result of irrigation seemed scarcely to justify the additional effort particularly in such years as 1906, 1911, and 1916 when more than 20 inches of precipitation were recorded. A sugar beet factory was established at Raymond in 1903 and was operated until 1913. Its failure may be attributed to inadequate irrigation of the beets, and to the relatively good price of grain which made wheat farming profitable. The sugar beet industry was revived in 1925, followed by the establishment of the canning industry. This, together with the prolonged period of dry weather and the low prices throughout the "thirties", brought the improved position of the irrigation farmer into sharp focus.

CLIMATE

The climate of southern Alberta is north temperate, and continental in type. However, the location of the Rocky Mountains and the prevalence of the Chinook winds have the effect of modifying the extremes usually incident to this type of climate.

Altitude

The altitude in the irrigated area varies from almost 4,000 feet above sea level on the west in the United Irrigation District through 3,000 feet at Lethbridge, 2,671 feet at Taber, 2,485 feet at Brooks, to 2,357 feet at Medicine Hat. Calgary, on the northwest corner of the irrigation development, is 3,437 feet above sea level.

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Temperature

As would be expected from the decrease in altitude, the temperatures become slightly higher from west to east across the area. The long-time mean annual temperatures at Calgary, Lethbridge, and Medicine Hat are approximately 39° F., 41° F., and 43° F., respectively. Differences in mean daily summer maximums (April through September) are even more pronounced; Calgary 66·5° F., Lethbridge 69° F., and Medicine Hat 72° F. Between Lethbridge and Taber, 30 miles eastward, there is a general increase in summer maximum and minimum temperatures of about 2° F. Over the past 50 years (1902-1951) Lethbridge has had an annual average of 140 days without a killing frost. (A killing frost is set arbitrarily as a temperature of 28° F. or lower). On the average, the latest killing frost occurs on May 8 and the earliest on September 26. The growing season gradually lengthens eastward from Lethbridge to Medicine Hat and shortens westward from Lethbridge toward the foothills. The United Irrigation District, near the mountains, suffers from a relatively short growing season. Generally speaking summers in southern Alberta are characterized by slightly cooler days and considerably cooler nights than many irrigated areas in continental United States. Mean maximum and minimum temperatures for Lethbridge are compared with two well-known irrigated areas in the United States in Table 1.

TABLE 1—COMPARISON OF THE MONTHLY AVERAGE DAILY MEAN MAXIMUM AND MEAN MINIMUM TEMPERATURES IN DEGREES FAHRENHEIT OF TWO IRRIGATED AREAS OF THE UNITED STATES AND LETHBRIDGE, ALBERTA

MONTH	LETHBRIDGE, ALBERTA		FORT COLLINS, COLORADO		SALT LAKE CITY, UTAH	
	Max.	Min.	Max.	Min.	Max.	Min.
May.....	62·7	37·4	67·0	40·3	71·8	44·9
June.....	67·6	46·3	76·1	48·1	81·7	52·1
July.....	80·8	50·9	85·5	54·7	92·4	61·4
August.....	76·6	47·5	84·4	54·5	89·7	59·4
September.....	65·4	40·6	76·2	43·0	79·0	49·1

Precipitation

The precipitation records of the Experimental Station at Lethbridge for the past 50 years are shown in Table 2. Precipitation throughout the area varies directly as the altitude and inversely as the temperature. Whereas the average precipitation at Lethbridge is approximately 16 inches, it is 19 inches in the United Irrigation District, 13 inches at Taber, and 14 inches at Brooks. Over the whole area 75 to 80 per cent of the moisture falls during the crop season. Superficially it may seem that the amount of precipitation is of little consequence under irrigation farming. However, in actual practice the rainfall is of considerable importance. Sufficient spring rainfall to germinate the crops is highly advantageous because of the attendant difficulties of "irrigating up". In the fall, the soil may be irrigated and brought to the optimum moisture content for harvesting but if heavy rains follow, harvesting may become very difficult. This is especially true with root crops.

TABLE 2—MONTHLY PRECIPITATION AT THE EXPERIMENTAL STATION—
LETHBRIDGE, ALBERTA FOR 50 YEARS, 1902-1951

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1902.....	0.67	1.03	0.48	0.02	11.27	5.68	5.95	0.69	0.84	0.02	0.43	0.84	27.92
1903.....	0.62	0.79	0.89	0.33	2.95	1.12	1.86	3.21	1.60	0.17	0.58	0.70	14.82
1904.....	0.50	0.90	1.03	0.41	2.86	1.80	0.96	1.19	0.52	0.85	0.03	0.35	11.40
1905.....	1.45	0.05	0.74	0.56	1.33	2.68	1.44	1.99	0.80	1.13	1.36	0.25	13.78
1906.....	0.22	0.20	0.54	1.30	8.60	2.31	0.83	4.70	0.16	1.93	0.81	0.88	22.48
1907.....	1.52	0.30	0.34	1.08	1.14	3.64	1.43	2.30	3.24	0.05	0.14	0.32	15.50
1908.....	0.27	0.75	0.79	0.69	2.60	7.01	0.42	0.90	0.58	0.57	Nil	0.36	14.94
1909.....	0.30	0.20	0.50	1.15	4.01	0.82	1.54	0.08	0.47	0.37	0.46	0.42	10.32
1910.....	0.24	0.83	0.17	0.28	0.79	0.53	0.09	1.07	1.95	0.60	0.41	0.94	7.90
1911.....	0.70	0.52	0.32	0.82	1.90	4.70	2.27	3.63	4.16	0.57	0.95	0.77	21.31
1912.....	0.69	0.40	0.44	0.20	0.66	1.73	2.78	1.41	2.61	1.07	0.99	0.23	13.21
1913.....	0.80	0.30	0.42	0.52	1.70	4.70	1.29	1.93	1.65	0.50	0.36	Nil	14.17
1914.....	1.55	0.96	1.12	0.54	0.29	2.48	0.93	3.59	1.07	2.17	0.63	1.19	16.52
1915.....	0.50	0.94	0.22	0.04	3.03	4.84	3.44	0.96	1.32	0.96	0.75	0.27	17.27
1916.....	1.09	0.86	0.90	0.46	3.77	3.54	3.33	2.97	4.96	1.99	0.49	0.51	24.57
1917.....	0.73	0.27	0.10	1.57	0.95	1.42	1.37	2.00	1.67	0.82	Nil	1.13	12.03
1918.....	0.46	0.76	0.66	0.13	0.58	0.76	0.85	1.23	1.07	0.24	0.43	0.46	7.63
1919.....	0.06	0.95	0.75	0.47	1.75	0.56	1.06	1.05	2.04	1.78	1.26	0.55	12.28
1920.....	0.84	1.21	0.89	4.37	1.66	0.40	2.59	0.20	0.05	0.99	0.06	0.79	14.05
1921.....	0.56	0.47	1.42	1.19	0.96	1.04	3.23	0.46	1.29	0.23	1.73	0.19	12.77
1922.....	0.43	0.41	0.81	2.57	0.89	1.87	2.50	0.40	0.81	0.78	0.47	0.60	12.34
1923.....	0.48	0.42	0.75	1.09	3.48	4.45	2.55	1.01	0.18	0.55	0.53	0.91	16.40
1924.....	0.66	1.04	0.69	0.56	1.17	3.82	0.54	2.91	1.46	0.59	1.02	1.54	16.00
1925.....	0.30	0.99	2.26	1.99	0.43	3.40	0.82	1.85	4.86	1.08	0.16	0.62	18.76
1926.....	0.26	0.70	0.11	0.34	0.64	4.67	1.15	2.31	4.62	0.31	0.52	0.56	16.19
1927.....	0.31	1.39	0.37	1.48	7.32	1.60	1.93	1.74	3.29	0.58	2.88	0.96	23.85
1928.....	0.94	0.79	0.93	1.32	0.09	6.79	3.98	1.54	0.24	0.85	0.28	0.33	18.08
1929.....	1.08	0.63	1.34	2.55	2.63	3.72	0.52	0.59	2.05	2.20	0.49	1.91	19.71
1930.....	0.37	0.20	0.77	1.53	1.54	1.42	1.87	0.57	2.36	0.58	0.92	0.21	12.34
1931.....	0.01	0.25	1.40	1.12	1.22	1.55	1.09	0.19	1.99	0.66	1.21	0.73	11.42
1932.....	0.81	0.55	1.06	2.73	2.99	2.06	0.74	3.63	1.00	1.07	1.87	0.74	19.24
1933.....	0.33	0.38	2.51	2.49	1.80	1.32	0.92	2.64	1.30	2.44	0.77	2.27	19.17
1934.....	0.43	0.31	2.30	0.13	0.71	4.00	0.43	0.60	2.97	1.70	1.11	0.59	15.28
1935.....	0.47	0.72	1.09	2.46	1.42	0.35	0.70	1.18	0.22	1.70	0.52	0.47	11.30
1936.....	1.19	0.62	0.98	0.78	2.01	1.89	0.41	0.90	1.39	0.69	0.48	1.40	12.74
1937.....	1.76	0.42	0.79	0.45	2.38	3.19	2.19	0.86	1.10	1.33	0.70	0.38	16.27
1938.....	0.91	0.80	1.85	0.88	3.21	1.16	1.28	1.72	0.81	0.96	1.93	0.22	15.73
1939.....	0.12	0.88	0.74	0.68	1.66	6.42	0.58	0.38	2.10	0.96	0.29	0.82	16.53
1940.....	0.03	1.43	0.63	3.47	1.32	1.25	1.72	0.39	1.57	1.37	1.03	0.38	14.59
1941.....	0.96	0.68	0.71	1.09	1.96	2.67	4.09	1.80	2.82	0.25	0.36	0.34	17.73
1942.....	0.11	1.21	0.64	1.06	4.61	4.34	3.22	1.00	1.49	0.20	1.44	0.26	19.58
1943.....	1.06	0.67	0.83	0.81	1.33	0.90	1.46	1.15	0.83	1.11	0.10	0.03	10.28
1944.....	0.10	1.33	1.08	1.08	1.52	1.76	2.92	1.69	1.05	Nil	2.00	0.57	15.10
1945.....	0.70	1.33	0.82	1.14	3.18	3.48	1.17	0.88	3.26	0.51	0.91	1.65	19.03
1946.....	0.54	0.29	0.30	0.43	2.18	4.43	1.01	1.49	1.97	4.37	2.51	1.48	21.00
1947.....	0.77	1.41	2.10	1.61	0.56	4.24	0.35	2.77	3.45	0.96	1.01	0.72	19.95
1948.....	0.90	1.68	1.39	1.14	4.24	6.06	2.02	0.10	Nil	0.52	0.55	0.35	18.95
1949.....	1.62	0.91	1.63	0.15	3.70	1.30	0.96	0.46	0.62	2.55	0.08	1.46	15.44
1950.....	1.15	0.32	1.51	1.00	0.91	1.33	1.77	0.78	0.89	0.97	1.20	0.59	12.42
1951.....	1.18	0.99	1.17	2.74	1.28	6.28	0.94	3.74	2.14	2.46	0.15	2.12	25.19
50-Year Average	0.68	0.73	0.92	1.14	2.30	2.87	1.68	1.54	1.69	1.03	0.79	0.73	16.09

Evaporation

The combination of strong winds and hot summer weather results in a high evaporation rate in southern Alberta. The evaporation from a free water surface during the summer months is shown in Table 3.

TABLE 3—MONTHLY EVAPORATION IN INCHES FOR AN 11-YEAR PERIOD AT THE EXPERIMENTAL STATION, LETHBRIDGE, ALBERTA

Year	May	June	July	Aug.	Sept.	Oct.	Total
1940.....	4.56	3.88	4.82	5.98	5.77	3.81	28.82
1941.....	4.30	3.22	5.95	3.63	2.58	1.51	21.19
1942.....	4.02	4.07	4.54	3.45	2.46	1.70	20.24
1943.....	3.77	3.27	6.07	5.76	3.98	3.38	26.23
1944.....	2.93	2.74	4.95	5.13	3.14	1.43	20.32
1945.....	3.35	3.77	5.83	4.79	3.06	1.57	22.37
1946.....	4.02	3.83	5.54	4.50	2.79	1.34	22.02
1947.....	4.23	3.97	7.89	4.00	1.70	1.59	23.38
1948.....	2.44	3.76	4.68	4.48	3.65	1.99	21.00
1950.....	4.85	4.25	4.85	4.71	3.92	2.81	25.39
Average.....	3.85	3.68	5.51	4.64	3.30	2.11	23.10

Sunshine

The Lethbridge district has more sunshine and more wind than any other populated area in Canada. The monthly hours of bright sunshine at Lethbridge for the 10-year period (1939-1948) are shown in Table 4.

TABLE 4—MONTHLY HOURS OF SUNSHINE FOR THE 10-YEAR PERIOD 1939-1948 AT LETHBRIDGE, ALBERTA

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1939.....	98.5	125.4	190.7	215.9	301.1	208.5	368.7	297.2	200.0	165.2	135.3	79.1
1940.....	75.6	74.4	101.0	136.1	279.8	325.7	297.5	328.6	212.2	135.5	94.4	111.4
1941.....	74.3	144.9	193.4	239.4	240.8	275.8	343.4	254.3	171.2	186.9	113.2	123.6
1942.....	130.7	96.6	173.1	215.5	208.1	207.3	315.8	280.2	192.0	145.6	85.1	69.9
1943.....	95.1	148.6	150.3	241.8	267.7	244.4	378.7	335.5	269.8	192.7	150.1	118.8
1944.....	126.7	109.9	170.4	253.2	268.5	255.7	347.1	289.5	230.5	225.8	89.9	89.3
1945.....	112.4	126.9	169.4	174.3	252.2	231.9	361.1	318.0	165.9	172.6	77.7	75.7
1946.....	103.9	111.7	174.6	229.0	240.0	274.5	355.9	281.6	177.2	152.3	96.5	97.6
1947.....	83.7	120.3	160.2	227.2	276.2	232.9	373.2	246.6	171.8	161.9	79.6	79.8
1948.....	106.0	116.3	156.4	186.0	226.7	220.3	337.9	325.7	240.5	215.8	105.9	104.7
Monthly Average..	100.7	118.1	164.0	211.8	256.1	247.7	347.9	295.7	203.1	175.4	102.8	95.0

In addition to abundant sunshine, southern Alberta, by virtue of its northern latitude, also enjoys long summer days. This is a distinct advantage in agricultural production. In Table 5 the total hours of daylight (sunrise to sunset) at Lethbridge and Salt Lake City, Utah, are compared. The latitude of Salt Lake City is roughly representative of much of the irrigated land of western United States.

TABLE 5—TOTAL HOURS OF DAYLIGHT (SUNRISE TO SUNSET) AT LETHBRIDGE AND SALT LAKE CITY DURING THE SUMMER MONTHS

—	May	June	July	Aug.	Sept.	Total
Lethbridge.....	477.9	488.7	492.1	447.4	378.3	2,284.4
Salt Lake City.....	448.2	451.0	457.5	427.0	374.1	2,157.8

Wind

Chinook winds are an important feature of the climate of the more southerly irrigated areas in Alberta. These warm, dry winds occur throughout the year and result from warm air masses originating in the Pacific area moving eastward over the Rocky Mountains. Sweeping over the prairies, often at velocities of 40 to 50 miles per hour, they cause rising temperatures and rapidly melting snow in winter and excessive evaporation and transpiration in summer. The monthly mean velocity of wind in miles per hour at Lethbridge for the 10-year period (1939-1948) is shown in Table 6.

TABLE 6—MONTHLY WIND MILEAGE FOR THE 10-YEAR PERIOD 1939-1948 AT LETHBRIDGE, ALBERTA

(Recorded by an anemometer on a 30-foot tower)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1939.....	9,649	5,470	7,757	12,344	12,427	8,917	10,868	8,777	10,698	12,947	13,865	13,837	127,556
1940.....	8,816	7,224	10,928	10,461	10,785	8,820	8,530	9,315	7,247	11,325	3,558	12,465	109,474
1941.....	9,252	8,690	9,278	9,845	12,286	9,828	8,904	8,034	10,102	12,130	13,982	12,301	124,632
1942.....	14,326	8,198	12,494	11,551	9,335	11,090	8,641	6,581	7,954	12,288	10,625	10,449	123,532
1943.....	10,451	11,916	11,445	12,073	10,886	10,779	11,015	10,241	10,630	9,005	10,830	14,306	133,577
1944.....	14,039	11,238	11,350	9,329	10,670	10,152	8,884	9,413	10,419	10,633	8,539	10,837	125,503
1945.....	9,183	10,589	13,102	10,959	9,622	9,620	8,625	8,840	9,933	11,929	9,600	10,501	122,503
1946.....	16,414	11,987	13,289	14,095	9,073	9,547	9,078	9,093	9,891	13,322	9,265	14,297	139,411
1947.....	17,671	8,682	6,309	11,533	10,225	7,123	8,726	8,749	10,560	12,632	8,849	12,777	123,836
1948.....	13,890	11,297	11,406	9,899	10,724	7,333	8,373	9,951	9,888	11,427	13,547	10,055	127,790
Monthly Average	12,369	9,529	10,736	11,209	10,603	9,321	9,164	8,899	9,732	11,770	10,266	12,182	125,781

SOIL

The irrigated areas of Alberta lie within provincial soil zones 1 and 2. Some of the larger existing irrigated areas include the Eastern Irrigation District of about 150,000 acres surrounding the town of Brooks, the Western Irrigation District of 20,000 acres immediately east of Calgary, the Lethbridge Northern District of 95,000 acres north of Lethbridge, and the St. Mary's River Development south and east of Lethbridge presently comprising more than 100,000 acres. Active construction of canals and laterals in this latter project is under way and eventually this development will add 300,000 acres of irrigated land. The proposed Red Deer project near Hanna is still in the preliminary planning stage, but may develop into an irrigated area of several hundred thousand acres.

The projected additional irrigation development will be largely within zone 1. The soil of these zones has been formed by glaciation and varies in

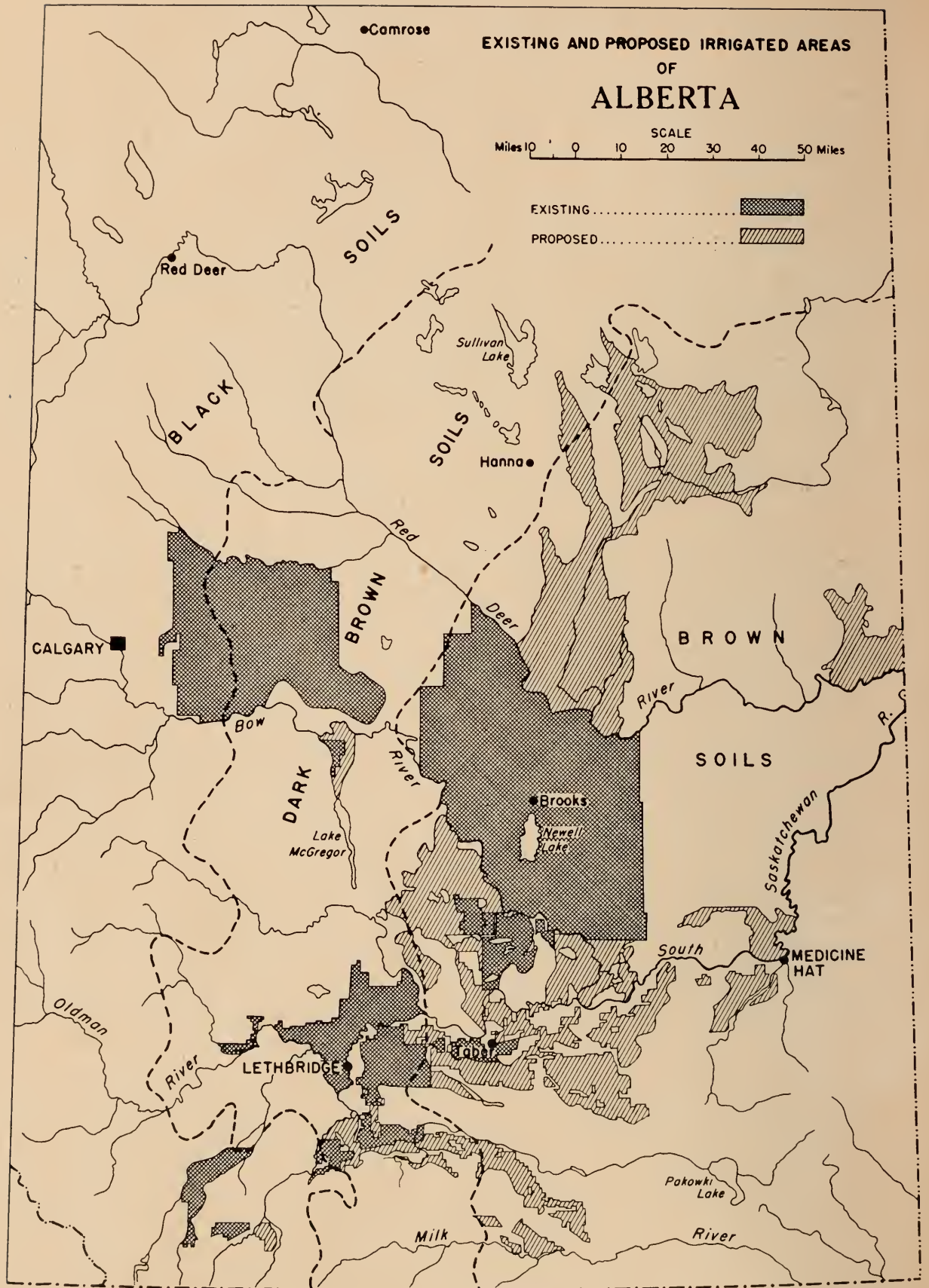


Fig. 1.—A map of part of the province of Alberta showing the existing and proposed irrigated areas in relation to the soil zones. Note that a very large percentage of the development is in the light brown soil zone.

topography from level to moderately hilly. Zone 1 is known as the light brown soil area and has about five inches of topsoil of a light brown to brown colour. This soil has developed under a short-grass vegetation and limited rainfall, and has approximately 2 per cent organic matter in the first foot of soil. In general the irrigated soils of zone 1 are intermediate in texture being mainly classified as loams or sandy loams. The soils of zone 2 are described as the dark brown soils. These have been formed from the same parent material as the soils of zone 1, but under higher moisture conditions and more abundant vegetation. Consequently the dark brown topsoil is about seven inches in depth and contains about twice as much organic matter as the light brown soils. The irrigated soils of zone 2 also are intermediate in texture although usually a little heavier than those of zone 1. There is a considerable percentage of clay loam and silty clay loam soil. Generally speaking soils of intermediate texture are most satisfactory for irrigation since they combine relative ease of working with fair moisture-holding capacity and satisfactory drainage.

Drainage

Good drainage is essential to successful irrigation. In general the irrigated soils of Alberta are underlain with comparatively permeable subsoils that allow satisfactory underdrainage. An exception to this occurs in the Eastern Irrigation District where there are substantial areas of hardpan or "blow-out" soils. However, under irrigation the relatively impervious hardpan seems to break up sufficiently to allow some root and water penetration and these soils have developed into fairly good irrigated soils. The heavy clay soils of some districts are inadequately drained and these present important local problems. Drainage problems become so important that their solution should be considered as soon as irrigation is begun. This applies with equal force to irrigation districts and individual farms.

METHODS OF IRRIGATING

All methods of irrigating have as an objective the uniform and efficient application of water to crop land. The simplest method is to convey the irrigation water in open ditches by gravity to the farm land and allow it to flood over a field, governed by gravity and surface topography. From this simple method, sometimes referred to as "wild flooding", methods increase in complexity and expense to the closed pipe systems that convey the water to the fields in pressure pipes and release it over the land through sprinkler heads or similar devices. The best methods provide a maximum coverage to a suitable depth with a minimum of waste, effort, and expense.

Ditches and dams

A field ditch is a special type of ditch that is partly above ground. The water level in the ditch usually approximates the ground level and hence by shovelling away a short section of the bank and introducing a dam to stop the forward flow the water can be diverted to the field. Dams are sometimes made simply by shovelling the necessary amount of soil into the ditch but a more convenient method is to use a canvas dam as illustrated in Fig. 2. Portable dams of light sheet iron or other materials are used also.

Wild-flooding

This loose method of irrigating is little used on irrigated farms, but finds a place in the irrigating of wild hay lands by spring flooding, etc. The water is conveyed to the land by ditches located to discharge the water so that it will flow over as wide an area as possible. The method is wasteful of water and effort, and uniform coverage is virtually impossible.



Fig. 2.—Canvas dams being used to divert water from a field ditch to a crop of barley.



Fig. 3.—Irrigation water flowing from a border ditch onto an alfalfa field. The field in the background will be irrigated with the two contour ditches which are visible.



Fig. 4.—A well-levelled, summerfallow field being irrigated with border ditches.

Flooding from contour ditches

Contour ditches are ditches that are surveyed throughout the field and which carry a slight uniform slope. This permits a moderate flow rate and allows the water to be turned onto the land at any point simply by cutting a hole in the bank. The surveyed slope of contour ditches is commonly $1/10$ of a foot per 100 feet and the ditches are placed from 300 to 600 feet apart throughout the field. This method of irrigating is used extensively on alfalfa and small grains in southern Alberta. It is applicable where land is relatively inexpensive and water is plentiful. It is not suited to intensively farmed areas or areas with limited water supply. Moreover considerable erosion of the soil takes place on sloping land that is not well anchored by a growing crop or crop residues. The experienced irrigation farmer soon learns at just what spot the ditch should be opened to provide coverage over a maximum area. Contour ditches are frequently used in conjunction with furrow or corrugation methods which are discussed below.

Border dike or border ditch flooding

On fields that have a uniform slope in one direction border dikes or border ditches provide a convenient method of control of irrigation. The dikes are simply low levees that are thrown up usually in parallel arrangement throughout the length of the field. The enclosed strips are levelled and the water is introduced at the top end of the field and allowed to run to the bottom, guided and restrained by the "dikes". The method is most appropriate for permanent pastures or hay fields since a minimum of disturbance of the levees occurs with these crops.

Border ditches are similar in pattern and operation except that the water is allowed to run down the ditches which mark off the field into strips and is then

turned out at successive intervals and allowed to flood until the intervening land is covered and sufficiently wetted. Border ditches are used in crops of small grains, peas, hay, and pasture fields. The ditches are easier than dikes to con-



Fig. 5.—Irrigation of a pasture field laid out with border dikes.



Fig. 6.—Thorough levelling is a prime prerequisite for successful irrigation by gravity methods.

struct and the former can be filled in readily to facilitate harvesting, etc. Border ditches should not be designed to run down steep slopes as this encourages erosion.

Border ditches are especially useful for irrigating level, flat lands as the ditch banks serve as borders to confine the water until the area between them is

covered; then the banks can be cut at intervals and the ditches serve as drains to carry off the surplus water. Basin flooding and check flooding are extensions of the border methods.

Furrows and corrugations

With the flooding methods described above the entire surface of the soil is made wet by the water flowing over it. When furrows or corrugations are used, less than half of the surface becomes wet, and this reduces both the loss from evaporation and the tendency of many heavy soils to puddle when saturated. Also the surface of the soil dries out more quickly thus permitting earlier cultivation after irrigation. Corrugations are sometimes differentiated from furrows as being smaller and more closely spaced but the distinction seems unnecessary.

Furrow irrigation is used on row crops such as corn, potatoes, and sugar beets. Corrugations or furrows also are used sometimes in irrigating cereal grains and alfalfa. On steeply sloping land it is better to have the furrows running across the slope rather than down it, this reduces erosion in the furrows and permits more percolation since the water is moving through the furrows at a slower rate. Water should not be run for too great a distance in furrows, 300 to 600 feet is the usual distance. Therefore cross ditches at right-angles to the furrows or contour ditches across the furrows are introduced at appropriate intervals and a new stream is initiated into each furrow. It requires careful adjustment to get just the right amount of water running in each furrow and uniform amounts in all furrows. The amount of water per furrow should be decreased as the slope of the land increases thus reducing erosion and allowing more time for penetration. With moderate slopes and medium textured soil a fair sized irrigation stream (2 c.f.s.) usually supplies 40 or 50 corrugations in a sugar beet field.

Siphon tubes and other control devices

A uniform rate of flow to each furrow can be assured by using curved siphon tubes as shown on the cover illustration. These tubes, made of plastic, aluminum, or pressure hose, are readily started and convey the water from the ditch over the bank into the furrow. A similar, although less convenient and satisfactory, method entails pushing short pieces of straight pipe through the ditch bank. Gated pipe, is sometimes used to deliver uniform streamlets of water to furrows. A simple and easily constructed device for providing uniform delivery to furrows is a V-trough made to any desired length from 1 inch by 6 inch boards nailed together at right angles. This trough carries the water across the headland and a 1-inch (or larger) hole is drilled through the board to deliver water to each furrow. This type of construction is particularly useful where the slope of the headland is steep or irregular, the V-trough can be supported on low trestles as it crosses low places. Small checks inserted into slots in the trough provide flow to each opening if necessitated by a rapid flow of the water.

The above devices have been mentioned as suggestive of methods of providing positive control of water in furrow irrigation. If it is remembered that it is desirable to provide uniform and efficient coverage and prevent waste and soil erosion, the ingenious irrigator will find many other ways to accomplish these ends.

Sprinkler irrigation methods

Irrigation by pressure methods from pipes has been in use for a number of years but has become much more extensive since World War II because of the availability of portable aluminum piping. Sprinkler systems simulate natural rainfall in their application of water; they are independent of surface topography and usually can be operated at a rate which will not bring about soil erosion. Thus sprinkler pipe systems can be employed successfully on land where irrigation by ordinary gravity methods would be impossible. In some areas pressure

is produced in sprinkling systems by carrying the water in pipes from a source on high ground to irrigate an area of much lower land. However, under prairie conditions, the more common method is to produce the necessary pressure by pumping. Pumps may be electrically driven or powered by gasoline, Diesel, or oil motors.

The sprinkler pipe systems of quick-coupling, portable aluminum tubing deliver water in one of two ways, (1) through small holes in the pipe (perforated pipe system), and (2) by sprinkler heads spaced at regular intervals along the pipe. These sprinkler heads are usually rotating but some types operate from a fixed position.

The advantages of sprinkler irrigation are as follows: (1) land levelling is not required; (2) uniform coverage and positive control of amount applied without wastage is possible; and (3) a less specialized type of labour is required with sprinkler irrigation than in usual gravity methods.

The disadvantages of sprinkler methods compared with ordinary hand methods are: (1) high initial cost; (2) higher operating cost in most cases; and (3) sprinkler systems require a specific amount of water and no provision is made for surplus or for handling the water during periods of mechanical break-down.

There is no doubt that sprinkler irrigation systems fill a real need on irrigated farms of rough topography, and likewise in intensive production of high quality crops where positive moisture control is necessary.

Points to remember in irrigating

The roots of most crop plants draw moisture and nutrients from the upper few feet of soil. This layer of soil acts as a storage reservoir for water and the object of irrigation is to keep this reservoir well supplied. On the other hand if the soil is kept saturated aeration will be lacking and plant growth will be retarded. About one acre-foot of water is required to completely satisfy the water-holding capacity of the upper six feet of a medium-textured soil.

Plants use the moisture from the top foot of soil first, followed by use from the second foot, third foot, etc. Therefore in irrigating the object is to replenish the water which has been used by applying enough water to connect up with the moisture in the lower depths. If more than this is used leaching and wastage occurs. Water should be applied before the crop shows any signs of wilting.

Some irrigation terms

An acre-foot of water is the amount of water required to cover one acre to a depth of one foot.

A cubic foot per second (c.f.s.) is a term indicating the rate of stream flow and implies that one cubic foot of water passes a given point each second. One c.f.s. flowing for 12 hours delivers approximately one acre-foot of water. Field irrigation streams usually vary from $1\frac{1}{2}$ to 3 c.f.s. On very flat lands larger streams, up to 6 c.f.s., are used to provide sufficient head.

A weir is a measuring device for determining the amount of water flowing past a given point. Some weirs have automatic recording devices.

The legal duty of water is the amount of water which the supplying agency must deliver to a farmer for each acre of land on which he owns water right and pays water taxes. This amount is fixed by statute. In Alberta the legal duty of water is $1\frac{1}{2}$ acre-feet.

The consumptive use of water by crops refers to the actual amount of water consumed by the crop and evaporated from the surface of the crop land in the production of the crop. Consumptive use thus includes rainfall. To determine the total amount of irrigation water necessary one must subtract the rainfall from the consumptive use and add thereto the amount of water that would be lost in conveyance, run-off, and deep percolation.

CROPS GROWN UNDER IRRIGATION IN ALBERTA

Alfalfa

The advantages of alfalfa as a forage crop are well known. Where conditions are favourable alfalfa usually occupies a large percentage of the land seeded down for hay production. In southern Alberta the well-drained, calcareous soils and the dry climate with abundant sunshine make this area favourable for alfalfa production where adequate moisture is available through irrigation. Alfalfa production in Alberta began with the development of irrigation, and this crop has been an important factor in stabilizing irrigation farming in this area.

Seed-bed preparation

A fine, firm, and moist seed-bed is a prime requisite for good germination of alfalfa seed. Such a seed-bed is more easily prepared on fall-ploughed land than on spring ploughing. Since the alfalfa usually is left down for several years it is important that the field be levelled to permit satisfactory irrigation. Generally speaking it is a waste of seed and effort to plant alfalfa on high sections of the field where irrigation water cannot be applied or on low spots where water will pond.

Method of seeding

Under irrigation alfalfa may be seeded with or without a nurse crop. If a nurse crop is used the alfalfa must be seeded through the grass-seeding attachment of the drill or in a separate operation in order that the seed may be placed not deeper than one inch. The cereal grains should be seeded at a reduced rate when used as nurse crops. Another method used at the Experimental Station, Lethbridge, is to seed the alfalfa in grain stubble, preferably barley, as soon as the grain crop is harvested in August. The seed may also be drilled into the stubble very early in the following spring.

Work in Colorado and elsewhere indicates that when barley is used as a nurse crop the yield of alfalfa in the first hay year will be reduced. The yield was not reduced when either flax or peas was used as a nurse crop.

At the Experimental Station excellent results have been obtained using canning peas as a nurse crop for alfalfa. Because of its less dense growth, wheat is better than oats or barley but all three are satisfactory.

Rate of seeding

Ten pounds per acre is the standard rate of seeding alfalfa for hay on irrigated land. Under poor seed-bed conditions the rate should be increased.

Irrigation

A good supply of moisture is essential to the establishment of a satisfactory stand of alfalfa. Irrigation applications should be made to suit the alfalfa rather than the nurse crop. When alfalfa is seeded with a cereal nurse crop it is necessary to irrigate more frequently than for a grain crop alone. Alfalfa has a very high water consumption. To produce a pound of dry matter it requires more than twice as much water as corn or sugar beets.

At the Experimental Station best yields of hay were obtained by applying three 6-inch irrigations, respectively, as follows: (1) early in May, (2) when the crop was 12 inches high, and (3) immediately after the first cutting. The yield was only slightly less when the early May irrigation was replaced by an application the previous fall. It is the usual practice to irrigate shortly before or immediately after the first crop of hay is cut in order to stimulate the growth of the second crop. In general, it is felt that irrigating shortly before the first

crop is cut provides for a quicker resumption of growth of the second crop. However, if the soil is unduly wet at cutting time, some difficulty in curing may be encountered.

Methods of handling

Hay making in an arid climate with irrigation supplied has many advantages. A large percentage of the hay grown on irrigated farms in southern Alberta is in the stack within four or five days after it is cut, usually with practically all the leaves still attached. Furthermore the original field greenness and a very high percentage of the nutrients and vitamins are preserved.

Two crops of alfalfa per year is the usual production in Alberta. However, frequently a third crop is available and when harvested provides a highly palatable feed of good quality. The first crop of hay is usually put up in late June or early July and the second about a month later. The third crop must be garnered early in October, at the latest, to avoid frost damage. Because of less favourable weather at this time of year the curing of the third crop is more difficult than the first and second crops. Alfalfa that is cut just before the onset of fall frosts is more susceptible to winter killing because of the depletion of the root reserves.

Alfalfa should be cut when it is one-tenth to one-quarter in bloom. If cut later than this the quality of the hay is lowered. If bloom is scarce cutting time may be gauged by the new shoots which develop from the crowns. The hay should be cut before these shoots become long enough to be clipped off by the mower cutter bar. In order to save the leaves alfalfa should be raked into windrows within a few hours after cutting. With favourable weather conditions it is possible to rake the hay with a side-delivery rake immediately behind the mower. If this practice is accompanied by good drying weather the original greenness, the nutrients, and the vitamins are preserved and a hay of very high quality is produced.

Bacterial wilt

Bacterial wilt is perhaps the most serious of all alfalfa diseases under irrigated conditions. It is caused by bacteria which enter the root tissues and cause a clogging of the water-conducting vessels. The affected plants exhibit smaller leaves and appear stunted and somewhat yellowish in colour. These symptoms are more pronounced in the second cutting than in the first cutting. When the bark of the root is peeled back the woody tissue appears yellowish or light brown whereas in normal healthy roots this tissue is white. Bacterial wilt usually does not affect an alfalfa field for the first two years after planting but in the third year diseased plants may be quite common. In most affected areas the economic life of alfalfa stands of susceptible varieties is limited to about three years. The disease is spread readily by the mower cutter bar and by irrigation water. There is no control for alfalfa wilt other than rotation and the use of resistant varieties. Good progress has been made in the United States in the development of resistant varieties. However, these resistant varieties have failed to show sufficient winter hardiness under Alberta conditions.

Alfalfa varieties

Grimm.—The original seed of this variety was brought to Minnesota by Wendelin Grimm, a German immigrant, in 1857. Through selection under the rigorous Minnesota winter climate a variety was developed with a high degree of winter hardiness. Grimm was introduced into Canada by the University of Saskatchewan and also by the Grimm Alfalfa Seed Growers Association of Alberta which was organized in 1913. Grimm has been the most popular variety grown in Alberta because of its winter hardiness and high yield. However, it is highly susceptible to bacterial wilt.

Ladak.—Ladak alfalfa apparently originated in India. It possesses some resistance to bacterial wilt and under Lethbridge conditions will usually hold a productive stand one or two years longer than Grimm. The first cutting of Ladak is much heavier than the first cutting of other varieties. However, Ladak recovers much more slowly and produces a later second crop. This is not such an important consideration in southern Alberta where only two crops are harvested.

Ferax.—Ferax is a variety developed by Dr. J. R. Fryer at the University of Alberta. It possesses the ability to set a large crop of seed and for that reason is popular with seed growers. It is also extremely winter hardy. However it is highly susceptible to bacterial wilt and yields less hay than Grimm.

Rhizoma.—Rhizoma is an alfalfa variety with creeping rootstocks developed by Dr. G. G. Moe of the University of British Columbia. Its creeping root habit causes it to form a dense sod. Rhizoma has given fair yields in British Columbia but has not shown especial promise under irrigation in Alberta. In addition it possesses little or no resistance to bacteria wilt.

Ranger.—Ranger alfalfa was developed co-operatively by the Nebraska Experiment Station and the United States Department of Agriculture. It is of recent origin and was developed to meet the need for a high yielding wilt-resistant variety for the mid-west and western states. It possesses high resistance to bacterial wilt and in tests in Alberta it has yielded only slightly less than Grimm. Unfortunately it does not exhibit sufficient winter hardiness to be widely recommended in Alberta.

Other varieties.—Viking, Cossack, Baltic, and Hardistan are other varieties which have been tested but have not shown especial promise. They have not become widely used primarily because of the difficulty of obtaining suitable seed stocks.

Development of new varieties.—At the present time the Department of Agriculture is sponsoring a very active alfalfa breeding program in Western Canada. It is expected that varieties will soon be available which will combine high yielding ability and winter hardiness with resistance to the more important diseases.

Alfalfa as a Soil Improving Crop

Alfalfa belongs to the legume family of plants. This group of plants is characterized by small nodules on their roots. In the nodules are bacteria, which take nitrogen from the air and convert it to forms usable by plants. However this ability of leguminous plants has been somewhat over-advertised and many have thought that infertile land seeded down to alfalfa for a few years becomes highly productive again. The truth is that alfalfa growing on most soils and being cut for hay brings about little soil enrichment although about two-thirds of the nitrogen required to produce the alfalfa is taken from the air. The alfalfa plant has two-thirds of its nitrogen in the tops and one-third in the roots. Thus the soil may be enriched in nitrogen if the green top growth is turned under, but this may not occur if the crop is cut continually for hay and no manure is returned.

Usually the physical condition of the soil is improved by growing alfalfa. The extensive root system penetrates deeply, improving the aeration of the soil and promoting the growth of beneficial bacteria. The decaying roots add to the supply of organic acids in the soil which in turn makes available plant food already present in the soil. However growing alfalfa definitely depletes the phosphorus supply. On Rotation "U", at the Lethbridge Experimental Station, which has been continuously in an alfalfa rotation since 1911, satisfactory yields cannot be obtained unless phosphorus fertilizer is added. The 10-year average

yields of alfalfa, fertilized and unfertilized, are shown in Table 7. Ammonium phosphate, 11-48-0, is applied at 100 lb. per acre to half of each appropriate plot three times in the 10-year rotation cycle.

TABLE 7—TEN-YEAR AVERAGE YIELDS (1937-46) OF ALFALFA HAY ON ROTATION "U" PLOTS WITH AND WITHOUT PHOSPHATE FERTILIZER

Production Year	Average Yields in tons per acre	
	100 lb. 11-48-0 per acre	No Fertilizer
First year Alfalfa.....	2.05	1.79
Second year Alfalfa.....	4.12	2.28
Third year Alfalfa.....	4.12	2.66
Fourth year Alfalfa.....	4.30	2.74

Land broken out of alfalfa of several years' standing usually has good physical condition and a satisfactory nitrogen level. Under Alberta conditions a good subsequent crop may be expected if phosphorus fertilizer is added. Alfalfa may indirectly improve the fertility of the soil if the hay is fed on the farm and the manure returned to the land.

Fertilization

As mentioned above, alfalfa has a high phosphorus requirement. To produce 4 tons of alfalfa hay requires 47 pounds of phosphate (P_2O_5) while to produce 40 bushels of wheat requires only 26 pounds of phosphate. Most of the alfalfa growing on irrigated lands in southern Alberta probably would respond to a phosphate fertilizer application.



Fig. 7.—The right half of the alfalfa field above received 100 lb. per acre of 11-48-0 fertilizer whereas the left half received none. The difference in dandelion infestation is apparent.

On some of the newer irrigated soils of Alberta additions of commercial fertilizer do not bring about increased yields of alfalfa. These are the thrifty, vigorous fields that yield three or four tons of hay per acre. However, many alfalfa fields show general unthriftness and low yields in the second and third years and also become seriously infested with dandelions. These fields likely have a phosphorus deficiency. As a general recommendation, 100 pounds of ammonium phosphate, 11-48-0, every other year of hay production should keep the field well supplied with phosphorus.

Alfalfa and weed control

Vigorous-growing alfalfa cut twice each year for hay will control Canada thistle, wild oats, and annual weeds. It is possible to establish an alfalfa field in thick patches of Canada thistle if the surface soil is kept moist until the young alfalfa plants are established. Experience at the Experimental Station has been that in the second year there are not enough thistles to affect the quality of the hay and by the end of the third season the thistles are completely eradicated. Dandelions frequently are troublesome in irrigated alfalfa fields in Alberta, but are not a problem in vigorous-growing alfalfa well supplied with phosphorus. Vigorous-growing alfalfa will check the spread of sow thistle but usually will not eradicate it. Nor will alfalfa control leafy spurge, Russian knapweed, field bindweed, or hoary cress. Field bindweed, particularly, will spread rapidly in an alfalfa field since it forms seed below the level of the mower cutter bar and these seeds are widely spread by the irrigation water.

The place of alfalfa in the rotation

Since alfalfa under irrigation will grow better than most other crops on relatively infertile soil, if adequate phosphorus is supplied, it usually is sown on land which has produced several consecutive crops. It may be left down for three years or longer if alfalfa wilt is not present. However, because of its beneficial effect on the soil the alfalfa should be moved around the farm until the whole area has been covered. When the alfalfa sod is broken up the first crop grown is usually one of the cereal grains or peas. Potatoes also do well immediately following alfalfa but it is difficult to prepare a suitable seed-bed for sugar beets and other small-seeded crops.

Alfalfa seed production

Considerable alfalfa seed has been grown on irrigated land, especially in the Eastern Irrigation District. When a field is planted to produce seed it is sown at a reduced rate, four or five pounds per acre. Thick stands tend to produce forage rather than seed. Excessive stands are sometimes thinned out by cultivation. Experience in Alberta has indicated that irrigation water should be applied sparingly to alfalfa seed fields.

There is a good deal of uncertainty associated with alfalfa seed production in Alberta, much of it related to the necessary tripping of the flowers. Wild bees are most adept in this operation. Leafcutter bees and bumblebees are efficient trippers of alfalfa; in seed-producing areas every encouragement should be given to increase their populations. Honey bees are relatively inefficient tripping agents but large numbers of these can do an effective job in increasing the seed set. Two or three colonies of honey bees per acre in an alfalfa field will materially assist in pollination and seed setting. Other plants such as wild sunflowers, gumweeds, sweet clover, etc., are competing nectar sources that attract bees from alfalfa blossoms and hence they should not be allowed to grow near the alfalfa seed field. Alternate damp and dry weather also seems to increase the seed set.

The mature seed usually is harvested with a combine. It may be swathed first and later threshed with a combine with a pick-up attachment. Under suitable conditions, the standing crop may be harvested directly with a combine thresher.

Sugar Beets

Sugar beets were first grown in Alberta during the period 1903-1913, but it was not until 1925 that production of this crop became an integral part of irrigated agriculture in this area. The acreage has increased from about 5,000 in 1925 to about 40,000 in 1952. During the past two decades sugar beets usually have been the most profitable field crop grown on irrigated land in southern Alberta. For this reason they have received first consideration in the planning of the farm rotation.

Choice of land

Sugar beets respond better than almost any other crop to highly fertile, well-prepared land. Under irrigation the loam soils generally are considered to be the most satisfactory. However, sugar beets are well adapted to a wide range of soil types, from rather heavy clays, to very sandy soils provided with ample moisture. Sugar beets will grow satisfactorily in soils containing a moderate amount of alkali salts but will not do well where the water-table is near the surface. In Alberta the best crops of sugar beets are grown on fertile, well-drained land of gentle slope to allow for uniform and thorough irrigation.

Seed-bed preparation

Whenever possible the land to be seeded to sugar beets should be ploughed and levelled in the fall. If the land has been fall ploughed and levelled the only spring operations required will be a light cultivation to destroy weed growth followed by several harrowings and a packing to pulverize the lumps and leave a fine and firm seed-bed. If the levelling is done in the spring, dry surface soil



Fig. 8.—A well-prepared seed-bed—soil is so firm that tractor wheel marks are barely discernible. No lumps larger than marbles are evident.

will be scraped into the low places to a depth of several inches and the loose soil removed from high spots, thus allowing the exposed surface to dry out and bake in the sun. It is impossible to secure uniform germination of small-seeded crops under these conditions.

Land which has grown a row crop the previous season and which has not been fall ploughed can best be prepared for seeding to sugar beets without spring



Fig. 9.—A cultipacker, or a land roller, is an indispensable implement in preparing a fine, firm seed-bed.



Fig. 10.—Seeding sugar beets requires extreme care. Note fineness and firmness of seed-bed, allowing for shallow planting and thorough packing of the seed row by the properly adjusted packer wheels. Straight rows make subsequent cultivations much easier.

ploughing. In this case a fairly deep cultivation to loosen the soil, followed closely by harrowing and packing to prevent loss of moisture, usually will result in a better seed-bed than is secured by spring ploughing and subsequent working down. When land must be spring ploughed, to turn under stubble, etc., it is important to pack and pulverize it well. The final seed-bed should contain few lumps larger than marbles, have ample moisture within one inch of the surface, and be so firm that a man walking across the field will leave the print of his heel and toe but not his instep. It is not safe to do this on light soils where there is danger of blowing.

Varieties of seed

Sugar beet seed is supplied to the grower by the contracting company. Sugar beet varieties are divided into three broad classes: tonnage (E strains), sugar (Z strains), and normal or intermediate (N strains). Much experimentation in Alberta has demonstrated that the highest returns in sugar per acre in this area result from the use of the tonnage strains. All seed now being distributed in Alberta is of the tonnage type. Varieties used originated in Europe and have been adapted to local conditions by selection and breeding. The most popular varieties are Kuhn (of Dutch origin) and S.K.E. (Sharpe's Kleinzwanleben Type E) which is a British improvement of a European developed variety. A field hybrid of these two varieties also has done well in Alberta.

Types of Seed

Whole seed.—The normal and entire sugar beet seed ball containing from one to five seed germs, each capable of producing one plant, is referred to as whole seed to distinguish it from the various processed seeds.

Efforts to break up the whole seed into single-germ pieces were successful in 1941. While not all the pieces germinated satisfactorily, this segmented seed contributed materially to the mechanical thinning of sugar beets.

Decorticated seed.—Segmented seed now has been wholly replaced by decorticated seed. The decortication process is accomplished by first scalping off the largest seed balls (which contain the highest number of germs) and subsequently subjecting the remaining seed to a rotary abrasive action which wears away much of the external corky material and dislodges some of the germs from multiple germ balls. The final product is a uniformly sized seed with much heavier bushel weight than whole seed and with much better flowability than either whole or segmented seed. It contains practically no "abnormal" or injured seed pieces but contains a larger percentage of double germ seed pieces than does segmented seed. Experience has shown that up to 30 per cent of the beets in the thinned stand may be doubles without reducing the yield. Thus decorticated seed provides a better stand than does segmented seed without lessening the possibility of mechanically thinning the beets or thinning them without stoop labour.

Single-germ seed.—Plant breeders now are making progress in the development of strains of sugar beets which will breed true for a high percentage of single-germ seed balls, and it seems probable that single-germ seed of satisfactory agronomic excellence will soon be available to beet growers. Considerable work on this phase of beet breeding is being carried out in Canada.

Date of seeding

The relatively short growing season for sugar beets in Alberta makes it necessary to seed as early as possible. The average yields of beets over a six-year period from seedlings on successive dates beginning April 20 are shown in Table 8.

TABLE 8—SIX-YEAR AVERAGE YIELDS (1931-36) OF BEETS IN A DATE-OF-SEEDING TEST AT THE EXPERIMENTAL STATION, LETHBRIDGE

Dates of Seeding	April 20	May 1	May 10	May 20	June 1	June 10
Yield (tons per acre).....	21.13	19.55	20.66	18.12	14.55	12.65

It appears from Table 8 that, on the average, beets may be seeded as late as May 10 without significant reduction in yield. However, earlier seedings are not disadvantageous and in some years produced considerably higher yields than beets seeded on May 10. The experiment was designed originally with April 10 as the first date of seeding, but it was possible to seed beets on April 10 in only one-half of the years of the test. Since the April 10 seedings in these years produced yields equal to those from any other date, seeding as early as possible is recommended. Sugar beet seedlings are susceptible to frost injury at the time of emergence and for a few days thereafter. After they have developed true leaves they are comparatively frost resistant.

Rate of seeding

The present recommended rate of seeding is 10 pounds per acre for whole seed. To have an emergent stand sufficient for mechanical thinning it is recommended that about 10 seed pieces per foot be planted. This requires approximately 7 to 8 pounds of decorticated seed per acre.

Methods of seeding

Modern sugar beet drills seed either four or six rows simultaneously. Sugar beet drills should never be operated faster than $2\frac{1}{2}$ miles per hour. The seed should be placed 1 to $1\frac{1}{2}$ inches deep, carefully covered and the soil well firmed about the seed pieces. All sugar beets in Alberta are seeded in rows spaced 22 inches apart.

Replanting

Every year a few fields approach the thinning stage with a poor stand of beets that cannot be thinned to more than 40 to 65 beets per 100 feet. The problem is whether to carefully salvage the best possible stand of beets or to reseed. A third alternative obviously is to abandon sugar beets on the particular field for that year and plant some other crop. If weeds or other modifying factors are not present and the stand of beets is the only consideration, more profitable results will usually be obtained by retaining the thin stand. Experiments in Colorado established that 50 per cent stands of timely planted beets gave a yield of roots equal to that received from replanted beets with 98 per cent stand.

Hand thinning

Optimum yields are secured with approximately 25,000 sugar beet plants per acre. This requires beets spaced slightly less than one foot apart in 22-inch rows. When the beets are thinned by hand the operation is begun as soon as the seedlings develop four true leaves. The thinners generally are instructed to attempt to leave 100 plants per 100 feet of row. The spacing between the nearest plants should be reduced to less than one foot if a blank space of more than one foot occurs in the row.

Pre-thinning weed control

Since mechanical harvesting of sugar beets is now an accomplished fact, the complete mechanization of the industry depends upon successful mechanization of the spring work. Perhaps more difficult to solve than thinning the beets

mechanically, is the control of weeds. It is not recognized generally that one-half of the labour at thinning time is expended on the removal of weeds. Therefore in order to produce a satisfactory crop of beets thinned mechanically, it is necessary to pay special attention to the weed problem. Only clean land should be selected for growing beets and all land should be worked immediately prior to planting to destroy germinating weed seedlings and thus give the beets an even break with the weeds. As soon as the weed seeds begin germinating, control must be started.

Implements for pre-thinning weed control

Spike tooth harrow.—Several implements will do a good job of spring weed control in beet fields. The ordinary spike tooth lever harrow is an excellent tool for weeding and mulching just prior to the emergence of the beets. In tests made by the Utah-Idaho Sugar Co., a cross harrowing with the teeth lying comparatively flat reduced the weed population by 50 per cent, and did not disturb the germinating seedlings; in fact, the stand of beets was increased 50 per cent by timely crust control. It is risky to stir the soil too much before the beet seeds have begun germination as this may dry out the surface soil excessively and lower the emergence stand. An ordinary harrow equipped with wheels provides positive depth control and prevents the harrow teeth from dragging and covering the small beets after they are up.

Finger weeder.—The finger weeder or bean weeder as shown in Fig. 11 is coming into popular use for weed control in beet fields. This implement can be used when the beets are very small. While it will destroy some beets, a much higher proportion of the weed seedlings will be eliminated. For best results the

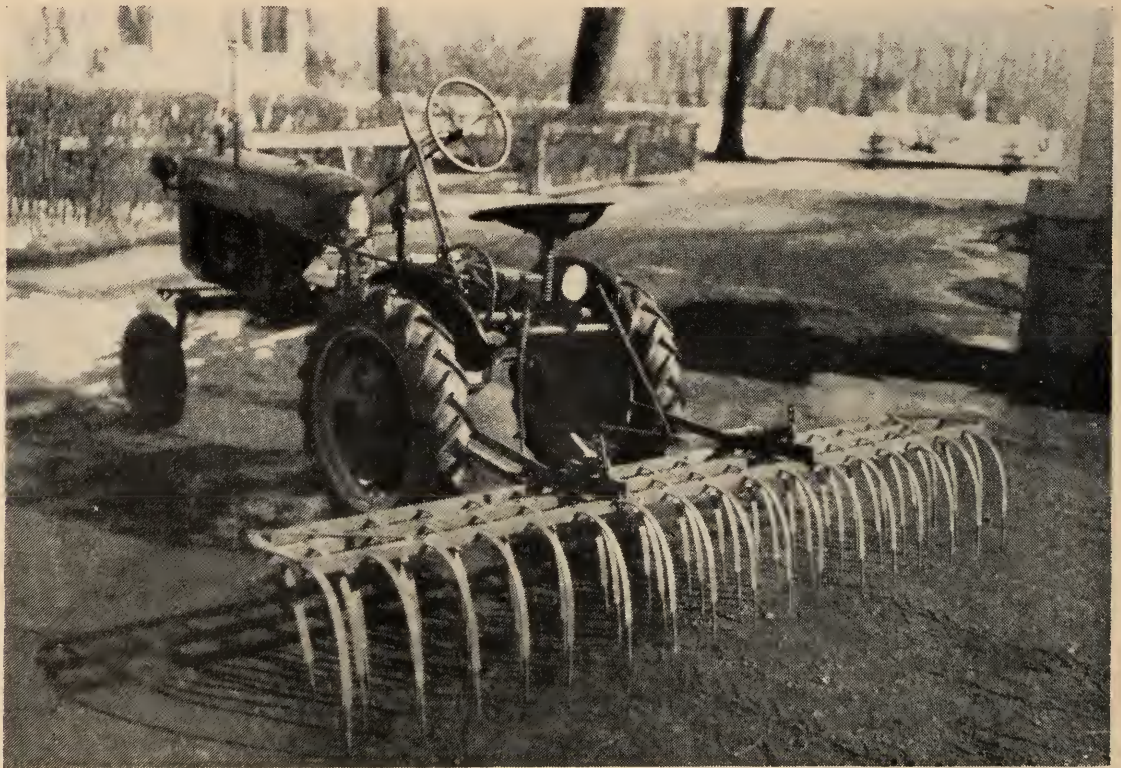


Fig. 11.—The finger weeder is a very useful implement for destroying weed seedlings in emerging row crops.

finger weeder must be used when the weeds and beets are both very small. This weeder is not a satisfactory beet thinner when the beets have six or eight leaves. However, it has been found by many farmers that three or four strokes with the finger weeder during the first two weeks after emergence will eliminate the weeds

almost completely and reduce the stand of beets to about the desired number. The beet field then does not need further attention until the time of the usual first hoeing when the remaining weeds are removed and the extra beets chopped out with long-handled hoes.

Side delivery rake.—In the case of the side delivery rake a new use has been found for an old implement. When used to eliminate weed seedlings shortly after the beets have emerged, the side delivery rake has done good work. It will not reduce the stand of beets materially unless they are very small. Some models of rakes require considerable adjustment to make the wheels fit the rows or to provide the desired amount of penetration of the revolving teeth into the soil. However, the success of this implement in many trials warrants its use in sugar beet weed control and mechanical thinning.

Rotary weeders.—There are several makes of down-the-row rotary weeders that do essentially the same job as the finger weeder and other tools discussed above. No one implement will do a complete job of mechanical thinning and weed control for all areas and all situations. However, the individual farmer usually can find a method that will suit his particular problem.

Estimating the stand

The greatest single deterrent to mechanical thinning in Alberta has been the fear of eliminating too many beets and thus leaving a poor stand. The desired harvest stand is 100 beets per 100 feet and the usual emergent stand is 300 to 600 beets per 100 feet. After the beets have emerged an estimate of the stand should be made. After each stroke of the harrow, weeder, or other implement, the stand should be estimated again to make sure that 100 beets per 100 feet of row still remain. A simple way to do this is to take a 25-foot length of sash cord and mark it off into one-foot lengths with fish line sinkers or daubs of paint; by having a stake in each end this can readily be extended over a 100-foot length of row and the number of beets counted. If this is done at 10 different spots in the field a very accurate estimate of the stand will be obtained. As long as there is one beet in each one-foot section, there is nothing to worry about and mechanical weed control across the rows or down the rows may proceed. At the Experimental Station, Lethbridge, a field of beets had an estimated emergent stand of 660 beets per 100 feet of row; after two strokes with the finger weeder there remained an estimated 390 beets per 100 feet.

Mechanical thinning

Frequently after the field has been gone over sufficiently to eliminate the weeds, the stand of beets has been reduced to about the desired density. If this is the case, the few extra beets can be left until the first hoeing and then treated as weeds. However, if the crop reaches the six-leaf stage with several hundred beets per 100 feet, it will be necessary to thin mechanically. The first step in mechanical thinning is to determine the existing stand. Since mechanical thinning is a more precise job than weed eradication it is necessary to have a finer appraisal of the stand than that discussed in the section above. This is usually arrived at by determining the number of beet-containing inches in 100 inches. This can be done with a yardstick or a simple device can be made by driving long finishing nails through a 1 inch by 1 inch wooden strip at 1 inch intervals. Eight beet-containing inches per 100 inches of row is approximately a perfect stand. If there are 16 beet-containing inches in this space, half of them must be removed; if 24 beets, two-thirds must be removed, etc. To accomplish this removal of two-thirds of the beets, it is only necessary to set the cutting tools to cut out a block twice as wide as the block that is left, for example, cutting out blocks 8 inches wide between undisturbed blocks 4 inches wide would provide the desired result. The principle is the same whether using a cross-blocker or a down-the-row blocker.

Cross Blocking with Beet Cultivator.—A satisfactory job of mechanical thinning can be done with an ordinary beet cultivator with the tools set on the tool bars at the necessary calculated spacing. In some areas the weeder disks and narrow duckfeet are used, one disk cutting away from each side of the undisturbed block and a duckfoot operating in the centre of the cut-out block. Another method is to use only weeder knives leaving the undisturbed block of the calculated width between the shoulders of one left-throw and one right-throw weeder knife. In either case it is necessary to stagger the cutting tools on the front and rear tool bars to provide maximum clearance. A marker is required on both sides of the machine.

Dixie Cotton Chopper.—This down-the-row rotary blocker can also be adjusted as to the size of block cut out and left undisturbed. It is available in 2-, 4-, or 6-row units. Its advantages are that it works better in trash than the cross-cultivator and is also better adapted to narrow fields and furthermore no difficulty with markers is encountered. It does satisfactory work in large beets or bad weed infestations.

Eversman (Soucie) Blocker.—The blocking tool of this down-the-row blocker is a notched disk that rotates through the rows leaving an undisturbed block when the notched out portion passes through the row. It is adjustable by changing the disks with variable notch widths and by varying the power take-off speed in relation to the forward travel speed.

Silver Thinning Machine.—This down-the-row machine is equipped with interchangeable rotary heads. The various heads provide for either weeding and mulching within the row or stand reduction for mechanical thinning. The machine has been used quite extensively in Alberta and usually has provided decided savings in hand labour.

Recommendations for mechanical thinning

(1) Make sure of a good stand of beets by seeding in a well prepared, fine, firm, clean, and moist seed-bed.

(2) Seed at least 6 pounds of decorticated seed per acre, pulling the drill at less than $2\frac{1}{2}$ miles per hour.

(3) As soon as any weeds germinate, go over the field with a harrow with the teeth well sloped. As the beets emerge, and immediately afterwards, eliminate more weeds by using a finger weeder or other implement. Continue as often as necessary to control weeds provided 100 beets per 100 feet of row remain.

(4) If too many beets are left after controlling weeds, cross block with beet cultivator or down-the-row blocker adjusted to cut out the proper number of beets.

(5) Do not leave more than 100 beets per 100 feet, including the doubles.

Cultivation

The chief purpose of cultivation in beet fields is to destroy weeds. Cultivation may be done also to provide aeration of the soil or to allow for better penetration of the irrigation water. In the Yakima Valley of Washington, where weeds are a considerable problem in beet fields, rather good weed control has been obtained by adroit cultivation. Immediately after thinning, the beets are cultivated with small "deer tongue" teeth, one of which operates on each side of the row. This operation pushes a little dirt up to the beets and covers small weeds which may be germinating in the row. A few days later, when the beets are a little larger, this operation is repeated using larger "deer tongues". This killing action is continued at intervals until the "deer tongues" are replaced by the irrigation shovels. In this way, weed control is accomplished with very little hand hoeing.

Pre-thinning cultivation usually is done with rotating disks cutting away from each side of the row, followed by knife weeder and duckfeet to cut out the weeds in the inter-row space. The disks should be set very close so that the beets are left on an undisturbed ribbon of soil not more than 3 inches wide. The narrow trench adjacent to the undisturbed ribbon left by the disk is filled in by the other tools. If open furrows are left on each side of the beet row, excessive drying results in slower growth and in addition more beets die after thinning because of lack of surface moisture.

Commercial fertilizer for sugar beets

In Alberta the standard fertilizer practice for sugar beets has been to apply about 100 pounds of ammonium phosphate, 11-48-0, per acre at the time of seeding the beets. Experience recommends placing part of the fertilizer directly with the seed to provide a readily available nutrient supply for the germination seedlings. Sugar beets thus fertilized frequently have been observed to emerge 2 or 3 days before comparable beets with no fertilizer closely available. The remainder is placed in bands alongside the seed. The beneficial effect of phosphorus fertilizer for sugar beets has been established beyond question.

The application of additional fertilizer as a side dressing to beets has been tried experimentally. Results indicate that many Alberta farms would produce increased yields of beets if additional nitrogen fertilizer were applied.

Manure for sugar beets

The yield of sugar beets is increased readily by the application of barnyard manure. In the beet-growing areas of Alberta most of the manure is applied directly ahead of the sugar beet crop. The manuring of sugar beet land will be discussed later in the general section on farm manure.

Irrigation

Sugar beets have a high water requirement, and it is important that the crop be well supplied with moisture throughout the entire growing season. Frequent light irrigations are more effective than heavy irrigations at longer intervals. Enough water should be supplied at each irrigation to connect up with the moist subsoil. At the Lethbridge Experimental Station best yields of beets have been obtained with three or four irrigations in addition to an irrigation the previous fall. Irrigation should be begun soon after thinning and repeated at two- or three-week intervals during the growing season so that the soil is kept moist at all times and the beets are maintained in an active growing condition. The last irrigation should be timed to leave the soil moist for harvesting. This not only makes harvesting easier, but decidedly increases yields and improves the storing quality of the beets.

In Alberta, sugar beets are irrigated by the furrow method. For best results the length of runs between cross ditches should be 100 to 150 yards depending on the slope of the land.

Harvesting

The sugar beet harvest in Alberta usually begins the last week of September in order that it may be completed by the end of October. This provides a maximum growing season of only five months which is considerably shorter than that available in many irrigated areas of the United States. Since the beets are growing rapidly and increasing greatly in sugar content toward the end of this short growing season, it is in the interest of maximum production to delay the harvest as long as possible. Gains of more than 30 per cent in per acre production of sugar have been measured in beets dug on October 23 as compared to beets dug on September 29.

Great progress has been made in sugar beet harvesting machinery during the last decade. Mechanical loaders have replaced hand methods and a number of satisfactory mechanical toppers have been developed. Generally speaking the cost of harvesting is reduced substantially by the use of machines and while improvements could and should be made, mechanical harvesting of beets can be said to have definitely arrived. Harvesting machines, when properly operated, do equally as efficient topping as ordinary hand labour. Studies in Alberta show that beets can be harvested by mechanical means at 65 per cent of the cost of usual hand methods.

Potatoes

Several thousand acres of potatoes are grown annually under irrigation in the Prairie Provinces. Since they are not grown under contract annual acreages vary greatly, depending upon prospective prices. Potatoes do well as an irrigated crop and careful attention to moisture supply from the time the tubers begin to form until harvest results in a product of high quality.

In addition to the cash return potatoes have other important advantages as an irrigated crop. A well-cultivated potato field provides excellent weed control. Potatoes are a good preceding crop; sugar beets, cereal grains, and most other crops produce well following potatoes. Cull potatoes are useful in a livestock feeding program. Because the potato crop usually is planted later than other special crops this work can be done when the pressure of the seeding rush is diminishing.

Choice of land

The lighter soils such as sandy loams or loams are preferable for potato production. However, heavier soils are satisfactory if they are carefully managed. Potatoes respond readily to well-prepared land of high fertility. Sod crops and green manure crops are very popular as preceding crops for potatoes. If the land is to be manured it is advisable to apply the manure during the season prior to the year the potatoes are planted as too much undecomposed organic matter in the soil favours the development of the organisms that cause scab. The topography of the land that is to be seeded to potatoes should lend itself to uniform irrigation; unirrigated portions of the field usually produce low yields, while low areas are easily drowned out by excessive moisture. One potato grower in the Lethbridge area has successfully solved the problem of irrigating on irregular land. This farmer ploughs down a green manure crop of sweet clover in July and immediately gives the field a thorough irrigation. Since no crop is growing he can use a fine network of ditches to make sure that the right amount of water reaches all portions of the field. The land is summer-fallowed for the remainder of the season and planted to potatoes the following spring, the potatoes receiving *no* irrigation water during the growing season. This practice has resulted in consistently better-than-average yields. Of course, high fertility, careful preparation and cultivation, and a soil of high moisture-holding capacity are prerequisites for potato production on fields that receive no irrigation during the growing season.

Seed-bed preparation

If potatoes follow a sod crop the first requisite in seed-bed preparation is obviously the ploughing of the land. This is best done in the summer preceding the potato crop. On alfalfa land the second crop should be ploughed under as green manure in August and the field should be well worked down and irrigated. On any type of land fall ploughing generally is superior to spring ploughing. In the spring, cultivations to destroy weeds and to mellow the soil to a depth of 5 or 6 inches followed by packing to preserve moisture are the main essentials. The ideal is a deep, mellow seed-bed, free from weeds and well supplied with moisture.

Planting

Carefully selected, properly cut and treated seed pieces are important in ensuring satisfactory stands. These cut sets should be protected from drying and injury. A good rule is to cut, treat, and plant the potatoes on the same day.

Under irrigation, potatoes are planted in 36-inch rows with one- or two-row mechanical planters. The sets are placed about 12 inches apart in the rows and this spacing may be narrowed somewhat on very fertile soils or widened out on soil of lower productive capacity. The seed pieces should be planted at a depth of 3 to 4 inches in moist warm soil. For successful planting the mechanical equipment should be in good repair and be operated at only a moderate rate of speed.

Fertilization

Many experiments in Alberta have indicated that the addition of fertilizer increases the yield of potatoes. Ammonium phosphate, 11-48-0, at the rate of 100 pounds per acre is commonly used. Table 9 gives the average yields of potatoes produced by eight different fertilizer formulations in comparison with a check plot receiving no fertilizer.

TABLE 9—AVERAGE YIELDS OF POTATOES IN A
REPLICATED FIELD TEST AT THE EXPERIMENTAL
STATION, LETHBRIDGE

(All fertilizers were applied at the rate of 110 lb. per acre.)

Fertilizer Formula	Yield in Tons per Acre
11-48-0*	10.19
8-10-5	9.60
2-16-6	9.50
9-27-9	9.44
2-19-0	9.00
8-32-4	8.89
4-12-8	8.83
0-38-0	8.15
Check	7.16

* See section on fertilizers for discussion of formulas.

The fertilizer may be applied to the land before ploughing or it may be applied with a fertilizer attachment on the planter at the time of seeding. Applications at planting time should be made in bands on each side of the seed row at a depth slightly below the seed pieces. The fertilizer should not come in contact with the seed pieces. As mentioned earlier, potatoes respond well to applications of barnyard manure but this is best applied during the season prior to planting the potato crop.

Cultivation

Cultivation of the potato crop begins as soon as any weed seedlings appear. Weeds are very easy to destroy during their first few days of life and no harm will be done to a properly seeded field by a light harrowing. The field may be harrowed several times before the potato plants emerge. A finger weeder (illustrated in Fig. 11), is a very effective implement for pre-emergence and post-emergence weed control and can be used for several weeks after the plants are up without causing injury. Cultivation with two-row cultivators usually begins as soon as the rows of plants can be seen and the first cultivation throws the soil toward the plants to smother small weeds in the row. As the plants become larger more soil is pushed into the row, ending with the final hilling operation which leaves adequate furrows for irrigating. Careful and timely cultivation generally will eliminate the need for hand hoeing.

The primary purpose of cultivation is to destroy weeds. Some growers also cultivate after each irrigation to assist in maintaining a mulch. This may be beneficial if it is carefully done but often close cultivation severs small rootlets and injures tubers and thus becomes harmful rather than beneficial.

Irrigation

Potatoes require very careful irrigation. The potato crop does not need so much water to produce a ton of dry matter as alfalfa or sugar beets, but with potatoes the amount and time of application are much more exacting.

When should potatoes be irrigated?—Potato plants should be kept in an active growing condition from emergence until harvest approaches. Any cessation of rapid growth even for short periods will be reflected either in reduced yield or lowered quality. This makes it necessary to apply irrigation water whenever the plants need it, *before* they show any signs of suffering from lack of moisture. A dry period during the first few weeks of growth, when the plants are small, will result in small vines with limited leaf area. It is essential to have large vines to ensure maximum food manufacturing capacity if high yields are to be obtained. A shortage of moisture at the time the tubers are being set is particularly objectionable. If fields are dry at this time a reduced number of tubers will be set, and if additional moisture is subsequently supplied these tubers are likely to grow into large, rough potatoes.

Method and Amount of Irrigation.—Potatoes are irrigated by running small streams of water down furrows between the rows. With potatoes, as with other row crops, more thorough and precise irrigation is possible if the rows run down a very gentle slope. One to two inches of fall per 100 feet is ideal. In medium to heavy soils irrigation furrows should be deep and narrow so that the water will not cause a saturated condition of the soil immediately around the tubers. In sandy soils the furrows are more satisfactory if they are shallower and wider thus bringing the water closer to the vines. The lateral movement of water is much greater in heavy soils than in light soils.

The length of time the water should be left running in a furrow depends upon the rate of percolation, slope of land, moisture content of soil, stage of plant growth, etc. Potatoes receive more than half their water requirements from the top 12 inches of soil, and more than three-quarters from the top 24 inches. This stresses the need of keeping the surface layers of soil well supplied with moisture, which necessitates frequent, light irrigations. At the Experimental Station, Lethbridge, on medium loam soils, it has been found necessary to irrigate, as lightly as possible, about every three weeks during the active growing season, extending or shortening the period between irrigations to compensate for rains or very dry spells.

Harvesting

Potatoes should be harvested early enough to avoid undue risk of frost damage. Careful irrigation is needed to bring the potato crop to maturity and have the soil at the proper moisture level for harvesting. Abnormally dry or wet weather can nullify the most careful efforts. Some growers remove the tops a few days before harvest; this hastens maturity and thus lessens the risk of damage during harvest. Root cutters that simply sever the roots and trim off spreading vines have been used in the past. Rotary beaters which have a series of rapidly revolving rubber paddles do a very thorough job of eliminating all top growth. There are a number of chemicals that may be sprayed or dusted to kill the vines without doing any harm to the tubers.

Potato diggers should be run deeply enough to carry considerable dirt on the digger chain and thus prevent bruising. It is impossible to dig potatoes in excessively dry, cloddy soil without doing considerable damage to the tubers.

Potatoes should be allowed to lie on the ground for an hour or two until the skin dries off and hardens a little; this will eliminate much subsequent cracking and scuffing.

Throughout the whole harvesting operation care should be exercised in handling since the market demands a high quality product. Picking bags should be only partly filled, truck boxes should be padded, and the potatoes should never be dumped into the storage cellars.

The Cereal Grains

On an irrigated farm the cereal grains usually are grown for feed rather than for sale, and hence nutrient content is important in the choice of one cereal grain over another. Barley produces a little more feed per acre than wheat or oats. Fifty bushels of barley contain about the same amount of feed material (total digestible nutrients) as 40 bushels of wheat, and land which produces 40 bushels of wheat will usually yield more than 50 bushels of barley. Wheat and barley are about equal pound for pound in feed value; a mixture of these two cereals makes a better grain ration for fattening livestock than either one singly.

Because oats are more palatable and bulky in nature, they have a place in the livestock fattening ration, particularly in starting stock on feed. In addition, oats are a very suitable feed for young, growing stock. It requires about 82 bushels of oats to equal 50 bushels of barley in feed value.

Cultural practices

The cultural practices for the cereal grains are well known. On irrigated land the seeding rates are relatively higher than on dry land— $1\frac{1}{2}$ bu. for wheat, $2\frac{1}{4}$ bu. for barley, and 3 bu. for oats being the usual rates.

Irrigation

In southern Alberta one application of about 6 inches of water will often produce a good yield of cereal grains. In extensive studies at Lethbridge, however, best yields of wheat were obtained with three applications, at 5-leaf, shot-blade, and flowering stages, or two applications at 5-leaf and flowering stages; one irrigation at shot-blade stage produced only a slightly lower yield. These studies showed that grain should be irrigated before the supply of moisture becomes short. Contrary to popular belief there was no ill effect from irrigating in the three-leaf stage before the plants shaded the ground.

It is not advisable to irrigate a heavy grain crop after it is in head as this predisposes the grain to lodging. Barley and oats lodge more readily than wheat, and because of this many farmers have grown wheat rather than barley for feed grain. However, a new variety of barley, Harlan, recently released for use on irrigated farms, has a very stiff straw and gives promise of overcoming this disadvantage.

When all factors are considered, the operator of a well-balanced irrigated farm likely will find it advantageous to grow an acreage of each of the three common cereals. In most cases, barley will occupy the largest share of the grain acreage as is indicated in Table 10.

Green Manure Crops

A green manure crop is a crop that is grown to be ploughed under for the purpose of improving the soil. Usually legume crops are utilized since they are able to take some nitrogen from the air and thus may enrich the soil. Other than nitrogen, no element can be added to soil by growing any green manure crop on it. The minerals necessary to grow the green manure crop must come from the soil. When the crop is turned under, these elements will be returned

to the soil—perhaps in a more readily available form than formerly. This “mobilization” of nutrients is one of the important advantages of a green manure crop. Another advantage is the addition of organic matter. The plant material of the growing green manure crop is manufactured from the carbon dioxide of the air and the water of the soil as well as mineral elements. Hence, when a crop is turned under, there is an addition to the soil of this organic material which the plant has manufactured. This added organic matter actually is only a very small percentage of the amount usually contained in a normal soil and therefore a single green manure crop should not be expected to greatly improve a soil that is badly depleted of organic matter.

Also, a green manure crop may improve the structure of a soil by increasing the aeration or by providing binding material for soil particles.

Sweet clover

Sweet clover is the most important green manure crop grown in southern Alberta. The common practice is to seed sweet clover with a cereal grain, generally wheat; the following year the green clover is ploughed under in June when the crop is in the bud stage and the land is irrigated and then fallowed for the remainder of the season. This treatment provides for a thorough decomposition of the green material, and the succeeding crop benefits from this abundance of readily available nutrients.

However, the practice of utilizing a full crop year to provide a green manure crop is difficult to justify economically. It would seem much more desirable to try to obtain the advantages of a green manure crop without losing the revenue from the land for one full season. It is common practice in regions with a longer growing period to plough down the crop in the late spring and seed the land to crop. This procedure is quite possible in southern Alberta but care in the selection of crops is necessary. A successful practice at the Experimental Station, Lethbridge, has been to plough under the clover crop about the end of May and seed the land immediately to canning corn. An average of $5\frac{1}{2}$ tons of canning corn have been produced over a 5-year period and the yield of beets the following year has been nearly as good as on comparable plots where the clover was ploughed under and the land fallowed for the remainder of the season.

Other green manure crops

Alfalfa and peas are other legumes that are used as green manure crops. The cereal grains also are sometimes used but since they do not increase soil nitrogen, their main advantage is the addition of organic matter. All green manure crops should be ploughed under in a succulent growth state and the soil should be kept moist to promote decomposition.

Irrigated Pastures

Not enough attention has been paid to irrigated pastures. Pasture should receive the same consideration as other specialty crops on the irrigated farm. There is a good deal of evidence to show that irrigated pastures marketed through dairy or beef cattle will produce a profitable return, equal to that from sugar beets or other specialty crops. Irrigated pastures in Utah produced 4,140 pounds of digestible nutrients per acre, which was converted into 200 pounds of butterfat by dairy cows and, according to calculations, would produce 972 pounds of beef on 600-pound steers.

Choice of land

It is no longer considered good practice to use only the roughest and least desirable arable land on the farm as a pasture. The pasture should be a part of the farm rotation and should be moved about the farm in order that all parcels

of land may receive the benefits resulting from a few years in sod. An arrangement such as depicted in Table 12, accomplishes this objective without having an unduly long cultivated crop rotation.

Pasture mixtures

There is still much to be learned in regard to what grasses and legumes are the most suitable for irrigated pastures in Alberta. A mixture of Kentucky blue grass and white Dutch clover has given good results in past years at Lethbridge. Pastures consisting largely of these species have repeatedly shown a carrying capacity of about 2 dairy cows per acre for the average 156-day grazing period.

More recent studies have established the superiority of orchard grass and ladino clover. These two species should be included in any good irrigated pasture where they are adapted. Orchard grass is very palatable and productive and recovers quickly after grazing. Ladino is a giant form of white Dutch clover and while it may lack a little in hardiness for Alberta, it should be included in all pasture mixtures in the Chinook belt because of its palatability and productiveness. The following mixtures are suggested:

- (1) Orchard grass..... 7 lb. per acre
 Brome grass..... 7 lb. per acre
 Creeping red fescue..... 7 lb. per acre
 Ladino clover..... 2 lb. per acre
- (2) A simple, highly productive mixture, which may, however, suffer damage from winter killing in severe winters is:
 Orchard grass..... 14 lb. per acre
 Ladino clover..... 3 lb. per acre

New information is being accumulated yearly on irrigated pastures and farmers are advised to consult their district agriculturist or Experimental Station, for the most recent data on mixtures.

Seed-bed preparation

Pasture grasses and legumes are the most demanding of all field crops in their seed-bed requirements. The soil must be worked until it is very fine and firm. The seed-bed should be packed well with a cultipacker. (See Fig. 9). Good results have been obtained by seeding directly into a clean stubble without previous working. Since uniform irrigation is indispensable to pasture production, the land must be thoroughly levelled before seeding. It is important that moisture for germination be very near the surface of the soil and sometimes this requires irrigation prior to seeding. It is not satisfactory to try to apply moisture for germination after seeding by the usual irrigation methods although newly seeded fields may be very successfully irrigated with sprinklers.

Nurse crop vs. no nurse crop

There is no arbitrary answer as to whether or not a nurse crop should be used. Generally speaking better stands have resulted where no nurse crop has been used; in addition the production during the first pasture year usually has been higher if the seeding is done without a nurse crop. The main advantages of a nurse crop are that it assists in weed control and provides revenue from the land while the pasture is being established. A nurse crop also protects the soil against erosion until the turf is formed. When a nurse crop is used (wheat is slightly superior to oats or barley but all three are satisfactory) it should be seeded at about one-half the normal rate and the irrigation should be applied according to the needs of the grass seedlings rather than the nurse crop.

Seeding

Shallow seeding cannot be stressed too strongly. One-half inch is the ideal depth for pasture grasses and legumes; poor germination and thin stands result when the seed is placed deeper than 1 inch. Drilling the seed shallowly into a firm seed-bed gives better stands than broadcasting.

Pasture management

As a general rule the pasture should not be grazed in the seeding year. Exceptions may be made if extreme care is exercised to prevent excessive tramping or close grazing of the young seedlings. In some cases the nurse crop has been successfully grazed off but this requires careful management.

Most efficient use of pasture is made by rotational grazing. If the field is divided into a series of paddocks the livestock can be moved from one to the other in order that they will always be grazing relatively young succulent growth. During the time when the grass is making its most rapid growth, it may be necessary to make hay of one or two paddocks in order to allow the animals to keep up with the pastures.

Irrigation

Pasture production under irrigation is particularly favourably adapted since generous application of water during the hot summer months maintains pasture at full production. In humid regions, where irrigation is not used, there frequently occurs a decided drop-off in pasturage during mid-summer. Rotational grazing makes it possible to irrigate pastures frequently and still allows sufficient time for the surface soil to dry before the stock are turned in.

Lush, rapidly growing forage plants have a high water requirement. Under Alberta conditions high-producing pastures will need about 18 inches of supplemental water per season. This is best applied in relatively small amounts and the usual practice is to irrigate a paddock as soon as the stock have been removed after grazing it down. Three or four irrigations per year are the usual number. Sprinkler irrigation is well adapted to pasture and by this means lighter amounts at more frequent intervals can be applied.

Canning Peas

Canning peas fit very well into the irrigated crop rotation. They provide a satisfactory cash return, a valuable livestock feed as a by-product, and other irrigated crops following them do well.

Choice of land

Peas do not compete well with weeds but otherwise are not difficult to satisfy in land requirement. Land which has grown cereal grain will produce a good crop of peas if weeds are not a problem. Peas are often sown on alfalfa breaking since volunteer alfalfa presents no problem in the canning pea crop and the land is preserved in high fertility for a following crop such as sugar beets. Peas produce satisfactorily after sugar beets but the converse sequence is much more advisable.

Seed-bed preparation

The seed-bed should be well worked and levelled to promote even germination and uniform irrigation. A deficiency in either of these essentials results in lack of uniformity in date of maturity and thus greatly reduces the return.

Seed and seeding

All canning peas are grown under contract to the processing companies. There are a number of varieties each of which fills a specific need in the processing industry. The early varieties usually are lower yielding than the later ones.

The number of days from seeding to harvest for each type is quite well known and farmers can thus request a variety to suit their cropping practices. The seed should be treated with fungicide (the mercury dusts are commonly used) prior to planting. The rate of seeding depends on the seed size but is approximately $2\frac{1}{2}$ to 3 bu. per acre. The seed should be drilled well into the moisture; $1\frac{1}{2}$ inches is the ideal depth but up to 3 inches may be satisfactory. If pea seed lies too long in cold soil it is likely to rot before germinating and thus greatly reduce the stand.

Fertilization

Fertilizers cannot be placed in direct contact with the germinating peas or damage will result. The usual practice in Alberta is to drill in 80 to 100 lb. of 11-48-0 per acre about one week before seeding the peas. Peas respond to careful manuring but large applications result in a preponderance of vines rather than seed pods.

Irrigation

It is essential that peas be maintained in an actively-growing, lush condition if a high quality canning product is to be produced. This means that adequate moisture must be supplied. At seeding time the land should contain sufficient moisture to germinate the seed and bring the crop along to a height of 6 or 8 inches. At this stage the ground will be shaded and the young plants will respond to an irrigation. A second irrigation shortly before harvesting will assist materially in producing green peas of good quality. Uniform irrigation is indispensable. Unirrigated spots or low areas where the water ponds produce no peas.

Harvesting

In Alberta the processing companies transport the viners to each farm and operate them, and the farmer is obliged to cut the peas and deliver them to the



Fig. 12.—Freshly cut green peas are fed into the viner. The shelled peas are delivered at the rear of the machine and the vines are carried out to a "silo" stack at extreme right.

viner for shelling. The harvesting methods range from cutting with a mower equipped with a wind-rower attachment and hand loading, to large cutters which windrow a 10-foot swath that is subsequently picked up and loaded by high-capacity green crop loaders.

The pea vines and shells remain on the farm and are usually converted into high quality silage in a large silo stack or they may be cured into hay, equal in quality to medium grade alfalfa hay.

Preservation of pea vines

An average acre of canning peas produces about two tons of hay or five or six tons of ensilage. If hay is to be produced, the green vines, as they come from the viner, are spread back on the field to dry and subsequently stacked or baled as with any other hay. Pea vine ensilage usually is made by building a large, circular stack of the green vines as they come from the viner (see Fig. 12). A good quality silage results if the vines are well compacted but there is usually a spoilage of about one foot on the exterior of the stack.

Place of peas in the rotation

The canning pea crop is garnered in July or early August before the annual weeds have gone to seed. The early harvest provides opportunity for a partial fallow of the field during the remainder of the summer. The land which has grown canning peas is an ideal place to spread the manure from the feedlot at a time when labour is usually available to put out manure. All of these factors combine to make the year after canning peas the favoured spot in the rotation and hence the place where the most profitable specialty crop is grown.

Canning Corn

Sweet corn for canning is an important crop on the irrigated lands of Alberta. A corn crop does not impoverish the soil so much as many other crops and the inter-row cultivation assists in weed control.

Choice of land

Corn may be planted on any well-prepared land on the irrigated farm and the return likely will be in relation to the fertility. In dry-land agriculture in this area corn is sometimes substituted for summerfallow. This has led to the belief that corn can be grown on land which has grown several crops and hence is relatively low in fertility. While corn does better than some other crops under such circumstances, a good crop of corn usually results from seeding on fertile soil. Canning corn grows well after alfalfa, sugar beets, or canning peas. On farms where good irrigated crop rotations are followed, the land manured, and the general fertility maintained at a high level, canning corn will produce a good crop following one of the cereal grains. Corn probably is suited better to this spot in the rotation than any of the other specialty crops.

Seed-bed preparation

Corn, being a large-seeded crop, does not require the fineness of seed-bed demanded by small-seeded specialty crops. The seed-bed should be firm and moist and recently tilled to check germinating weed seedlings. It should be well levelled also to allow for uniform irrigation.

Time of planting

Corn should not be seeded before the soil has warmed up in the spring because the seed is likely to rot in cold soil especially if planted deeply. In the Lethbridge area seeding usually is done early in May. However, plantings at the end of May produce satisfactory yields.

Seed and seeding

Canning corn is grown under contract to the processing companies who supply the seed. Hybrid varieties of suitable maturity for this area and of satisfactory canning quality are used. In Alberta, corn is grown in 22-inch rows since seeding and cultivating are done with the same machinery used for sugar beets. The seed is dropped at the rate of about two kernels per foot since it is desirable to have a final stand of at least one plant per foot in the row. The seed should be placed in moist soil at a depth of one to three inches. The shallower plantings germinate more readily and minimize the danger of seed decomposition.

Cultivation and weed control

Corn is regarded as a cleaning crop on the irrigated farm and as such it requires careful cultivation and frequently some hoeing. If emergence of the corn seedlings is slow it may be advisable to harrow the field to destroy small weeds which come up before the corn. If this is followed by close cultivation as soon as the rows are in evidence a clean crop of corn usually results. Some of the newer selective sprays have given promise for the control of weeds in corn and it is likely that this method will increase in popularity.

Irrigation

On a hot, windy day an acre of corn will use up an acre-inch of water. Water should be applied early enough to ensure that the plants do not suffer. On medium textured soils it is common practice to irrigate when the plants are one to two feet high and again about at the silking stage. An application of water a few days prior to picking improves the quality and weight of the crop.

Harvesting

Mechanical pickers for canning corn ears have been perfected and are in limited use but most canning corn grown in Alberta is still picked by hand. This demands a relatively high amount of hand labour since pickers average only three or four tons per day. The corn should be delivered to the processing factory as soon as possible after it is picked. In warm weather the sugar contained in the kernels changes very rapidly to starch and thus lowers the quality. The average yield of canning corn ears is about four tons per acre, with yields up to eight tons being common.

Sweet corn stover for fodder

After the canning ears are picked the stover remains green and succulent and can be made into a high quality silage. Because the sugar and protein content of sweet corn stover is high, silage made of this material approaches in value silage made from field corn, including the ears. Using a travelling field ensilage cutter the stover can be ensiled relatively cheaply and quickly and provides a high quality feed. Some growers pasture off their corn stover but much less feed is obtained in this way. The leaves and stalks soon become brown and dry and reduced in palatability.

After-harvest treatment of corn land

If the stover is cut and removed as silage the land is easily worked into a suitable seed-bed the following spring but if the stalks are pastured and remain standing in the field over winter it is difficult to work them into the soil. Because of the bulky material a loose, open seed-bed usually results. If the stover is not removed as silage it should be ploughed under and the land well packed during the fall. If necessary, it should be irrigated to provide sufficient moisture for decomposition.

Beans

String beans for canning are grown on a considerable acreage in Alberta. High yields of an excellent quality product have been obtained. Beans are very sensitive to frost but otherwise are well suited to this irrigated area. In a crop sequence experiment conducted at Lethbridge, beans as a preceding crop resulted in better yields of the succeeding crops the following year than were obtained after any other crop.

Pumpkin

Several hundred acres of locally produced pumpkin are canned in southern Alberta annually. This vine crop seems admirably suited to local conditions and the production could be greatly increased if suitable market outlets were available. As with other row crops, pumpkins provide an opportunity for inter-row cultivation and hence weed control. The wide spacing between the rows results in a degree of summerfallowing and this is usually reflected in a better-than-average yield of the crop following the pumpkins.

Other Specialty Crops

There are a number of other irrigated specialty crops which have been grown successfully in Alberta on a commercial basis. These include: carrots, table beets, cabbage, cucumbers, sunflowers, muskmelons, cantaloupes, strawberries, and raspberries. Although it has been established that a wide variety of specialty crops can be produced, it must be stressed that only a very small fraction of the potential production of these crops in this irrigated area has been realized.

CROP ROTATION

Crop rotation is a term that is familiar to all tillers of soil. However, its exact meaning is not generally understood. A true crop rotation is carried out only when a farmer has decided on a regular schedule of crop sequences and acreages and pursues it in such a manner that each field successively grows each crop, and a specific crop returns to a particular field at regular intervals. The practice of growing varying acreages of several crops, attempting each year to decide upon the most profitable and to avoid having one crop growing continuously on the same land is not strictly a crop rotation. A good illustration of a true crop rotation is the classic Rotation "U" at the Experimental Station, Lethbridge. This 10-year rotation comprises ten plots of 1 acre each, and five different crops as follows: (1) alfalfa (grown continuously for six years—thus requiring six plots), (2) oats (on alfalfa breaking), (3) barley, (4) sugar beets, (5) wheat (seeded down to alfalfa). This tract of land has been cropped in this manner since 1911 and provides an excellent example of the maintenance of fertility of irrigated soil under intensive crop production. However, Rotation "U" is not an ideal arrangement and serves to point out some of the difficulties associated with the selection of a suitable farm rotation. Sixty per cent of the farm growing alfalfa each year generally would be too much. Only 10 per cent of the acreage producing a valuable cash crop usually would be too little.

The ideal crop rotation

The ideal crop rotation should provide for maximum acreages of the most profitable crops. It should ensure a satisfactory and beneficial sequence of crops, maintaining or improving natural fertility. It should enable satisfactory control of erosion, weeds and other pests, and should permit an even distribution of labour and equipment requirements.

There are other advantages which usually are associated with crop rotation such as distribution of risks, more accurate forecasting of annual returns, and fuller utilization of available soil fertility. A fixed rotation also has some

TABLE 10—PERPETUAL CROPPING PLAN FOR A QUARTER SECTION OF IRRIGATED LAND SUPPORTING A 4-YEAR ROTATION OF SUGAR BEETS, BARLEY AND SWEET CLOVER, CANNING CORN, CANNING PEAS; AND A PLANNED CROP SEQUENCE OF ALFALFA, SUGAR BEETS, CANNING CROPS, AND CEREAL GRAINS ON THE REMAINDER OF THE FARM

Year	20 Acres	20 Acres	20 Acres	20 Acres	10 Acres	10 Acres	10 Acres	10 Acres	10 Acres	10 Acres	10 Acres	10 Acres	10 Acres
1951	Corn	Peas	Beets	Barley and Clover	Alfalfa	Alfalfa	Wheat and Alfalfa	Beets	Peas	Oats	Barley	Buildings, etc.	
1952	Peas	Beets	Barley and Clover	Corn	Peas	Alfalfa	Alfalfa	Wheat and Alfalfa	Beets	Barley	Oats	Buildings, etc.	
1953	Beets	Barley and Clover	Corn	Peas	Beets	Peas	Alfalfa	Alfalfa	Wheat	Oats	Barley	Buildings, etc.	
1954	Barley and Clover	Corn	Peas	Beets	Barley	Beets	Alfalfa	Alfalfa	Wheat and Alfalfa	Oats	Peas	Buildings, etc.	
1955	Corn	Peas	Beets	Barley and Clover	Oats	Barley	Peas	Alfalfa	Alfalfa	Wheat and Alfalfa	Beets	Buildings, etc.	
1956	Peas	Beets	Barley and Clover	Corn	Barley	Wheat	Beets	Peas	Alfalfa	Alfalfa	Oats	Buildings, etc.	
1957	Beets	Barley and Clover	Corn	Peas	Oats	Barley	Beets	Beets	Alfalfa	Alfalfa	Wheat and Alfalfa	Buildings, etc.	
1958	Barley and Clover	Corn	Peas	Beets	Wheat	Oats	Barley	Peas	Alfalfa	Alfalfa	Alfalfa	Buildings, etc.	

disadvantages; among these may be listed lack of flexibility, the necessity of growing some relatively unprofitable crops, and the inconvenience of a number of small fields often including temporary fencing.

Planned cropping program

An ideal crop rotation is difficult to obtain and frequently compromises are necessary. Because hay and pasture crops usually remain on the land for a number of years it is often advisable to remove these from the rotation proper thus conducting a true rotation on part of the farm and a planned crop sequence on the remainder. This method is illustrated in Table 10 which depicts a cropping plan for a quarter section of intensively farmed irrigated land in an area where both sugar beets and canning crops can be grown. It will be noted that one-half of the farm is divided into four 20-acre fields and supports a 4-year rotation of sugar beets, barley and sweet clover, canning corn, canning peas. The other half of the farm is divided into seven 10-acre fields and the farmyard, and produces a planned crop sequence of alfalfa and cereal grains and also 10 acres annually of each of sugar beets and canning peas. Thus the farm produces each year, 30 acres of sugar beets, 30 acres of canning peas, 20 acres of canning corn, 20 acres of alfalfa, 30 acres of barley, 10 acres of oats, and 10 acres of wheat.

Sequence of crops and field arrangement

The cropping plan of this whole farm is arranged to give the best possible sequence of all crops. Sugar beets always follow canning peas and, since on such a farm the pea land likely would be manured, irrigated, and conducted as a partial summerfallow after the peas are harvested in July, this would constitute the most favoured spot in the rotation and therefore should be devoted to the most profitable crop. The alfalfa is seeded with wheat as a nurse crop and the hay crop is harvested for three consecutive years. The program is so arranged that only 10 acres of alfalfa are broken up in any one year and similarly only 10 acres of new alfalfa would be seeded in any one year. Such practice would provide insurance against hay shortage when such matters as poor stands, lighter crops during the first year, etc. are considered. Furthermore, this method makes it easier to work out a cropping plan that will allow for the production of the same acreage of each crop, year after year. It will be noted that the two 10-acre fields of alfalfa always occur side by side thus adding convenience to irrigating and haying operations.

The canning peas follow corn in the 4-year rotation and on the other half of the farm the peas are seeded on alfalfa breaking in the years when this is available. In years when no alfalfa is broken up the peas are seeded after barley. Experiments have shown that canning peas produce well following corn and also cereal grains (see Table 11). This would be particularly true if the cereal grain stubble

TABLE 11—TWO-YEAR AVERAGE ACRE YIELDS (1949-50) OF VARIOUS IRRIGATED CROPS FOLLOWING OTHER CROPS IN A CROP SEQUENCE EXPERIMENT AT THE EXPERIMENTAL STATION, LETHBRIDGE

Preceding Crop	Peas	Corn	Potatoes	Barley	Wheat	Beets	Beans
Subsequent yield of:							
Barley (bu.).....	74.0	72.8	75.8	64.4	66.8	71.8	86.2
Wheat (bu.).....	48.2	49.4	48.0	42.6	46.5	42.8	51.4
Canning Corn (tons)....	6.99	6.35	7.39	6.36	6.34	6.58	7.30
Beets (tons).....	10.76	10.92	11.54	9.96	9.76	10.36	12.44
Beans (tons).....	0.89	0.97	0.98	0.89	1.69	0.76	1.15
Peas* (tons).....	1.04	0.96	1.18	0.98	0.84	0.78	1.25
Potatoes* (tons).....	6.93	7.21	5.07	5.32	6.34	6.49	7.08

* One-year average only.

was irrigated after the crop was taken off, lightly worked to encourage germination of weed and grain seeds, and finally fall-ploughed. Land which has grown canning peas makes an ideal place to apply manure from the feedlot. This is discussed fully in the section on manuring.

In the suggested 4-year rotation the canning corn is seeded after a barley crop which was seeded down to sweet clover for green manure. At the Lethbridge Experimental Station this practice has been followed with success for a number of years. The second-year growth of sweet clover is ploughed under as green manure about the end of May and the corn is seeded immediately afterward. Corn, being a gross feeder, makes very satisfactory growth under such conditions but the results with more delicate feeding crops such as sugar beets probably would be disappointing in Alberta.

The cereal grains follow sugar beets on 30 acres each year and this acreage of grain should always provide an excellent crop, thus guaranteeing a large proportion of the grain requirements for the livestock fattening program. The remaining 20 acres of cereals follow other grain crops and may be expected to yield a fair crop. These 20 acres assigned to grain production might be used to provide some flexibility in the cropping program and a farmer may wish to substitute an annual hay crop on part of this acreage or in case of weed infestation, or lowered fertility, he may elect to summerfallow a 10-acre field for one season and the following year plant a cash crop such as potatoes. However, the operator who lays out his farm for a number of years in some such cropping plan will experience considerable satisfaction in the orderliness and stability of his farming enterprise and will be reluctant to depart widely therefrom.

Since it is advantageous to soil structure and productivity to grow a perennial legume crop on land periodically, it would be advisable, about every eight years, to exchange the positions of the 80 acres supporting the 4-year rotation and the remainder of the farm which is laid out in the planned cropping program. This procedure would allow alfalfa to be grown in every field on the farm eventually. Such a practice together with the use of green manure and barnyard manure should maintain the soil of the whole farm in a satisfactory state of tilth and fertility.

Another cropping arrangement is illustrated in Table 12 wherein a quarter-section irrigated farm is divided into seven 22-acre fields, leaving 6 acres for the farmyard. These seven fields annually produce: alfalfa, irrigated pasture, and a five-year rotation of barley and sweet clover, corn, peas, potatoes, sugar beets. The alfalfa is left down for three years and the irrigated pasture for four years. In the appropriate year a new seeding of either alfalfa or pasture mixture is made with the canning peas or the seeding may be made in the summer after the canning peas are removed. Good results have been obtained with both methods at Lethbridge. In either case the hay or pasture would be ready for production the following year. Since potatoes follow peas in the five-year rotation this sequence would be interrupted by seeding down grass or legume with the peas and the potato crop would be shifted to follow the alfalfa or pasture sod, whichever was broken up. This is good practice since potatoes produce well following a sod crop.

The above cropping plans assume a uniform quarter section of land where it is possible to divide the farm into a number of fields of equal acreage. Frequently it is not possible to do this on an irrigated farm because of topography. Fig. 13 depicts a farm that may be more typical of many irrigated areas in that surface relief of the land makes necessary a division into a number of irregularly shaped fields of unequal acreages. However, this does not prohibit the designing of a suitable, perpetual crop plan. As an example a 9-year rotation has been devised

TABLE 12—PERPETUAL CROPPING PLAN FOR A QUARTER SECTION IRRIGATED FARM GROWING ANNUALLY 22 ACRES EACH OF ALFALFA AND PASTURE AND A 5-YEAR ROTATION OF CANNING PEAS, POTATOES, SUGAR BEETS, BARLEY WITH SWEET CLOVER, AND CANNING CORN

Year	6 Acres	22 Acres	22 Acres	22 Acres	22 Acres	22 Acres	22 Acres
1951	Farmyard	Alfalfa	Beets	Potatoes	Peas	Corn	Pasture
1952	Farmyard	Alfalfa	Barley and Clover	Beets	Potatoes	Peas	Pasture
1953	Farmyard	Alfalfa	Corn	Barley and Clover	Beets	Potatoes	Pasture
1954	Farmyard	Potatoes	Peas—seeded down to pasture in summer	Corn	Barley and Clover	Beets	Pasture
1955	Farmyard	Beets	Pasture	Peas	Corn	Barley and Clover	Potatoes
1956	Farmyard	Barley and Clover	Pasture	Potatoes	Peas—seeded down to Alfalfa	Corn	Beets
1957	Farmyard	Corn	Pasture	Beets	Alfalfa	Peas	Barley and Clover
1958	Farmyard	Peas—seeded down to pasture in summer	Pasture	Barley and Clover	Alfalfa	Potatoes	Corn

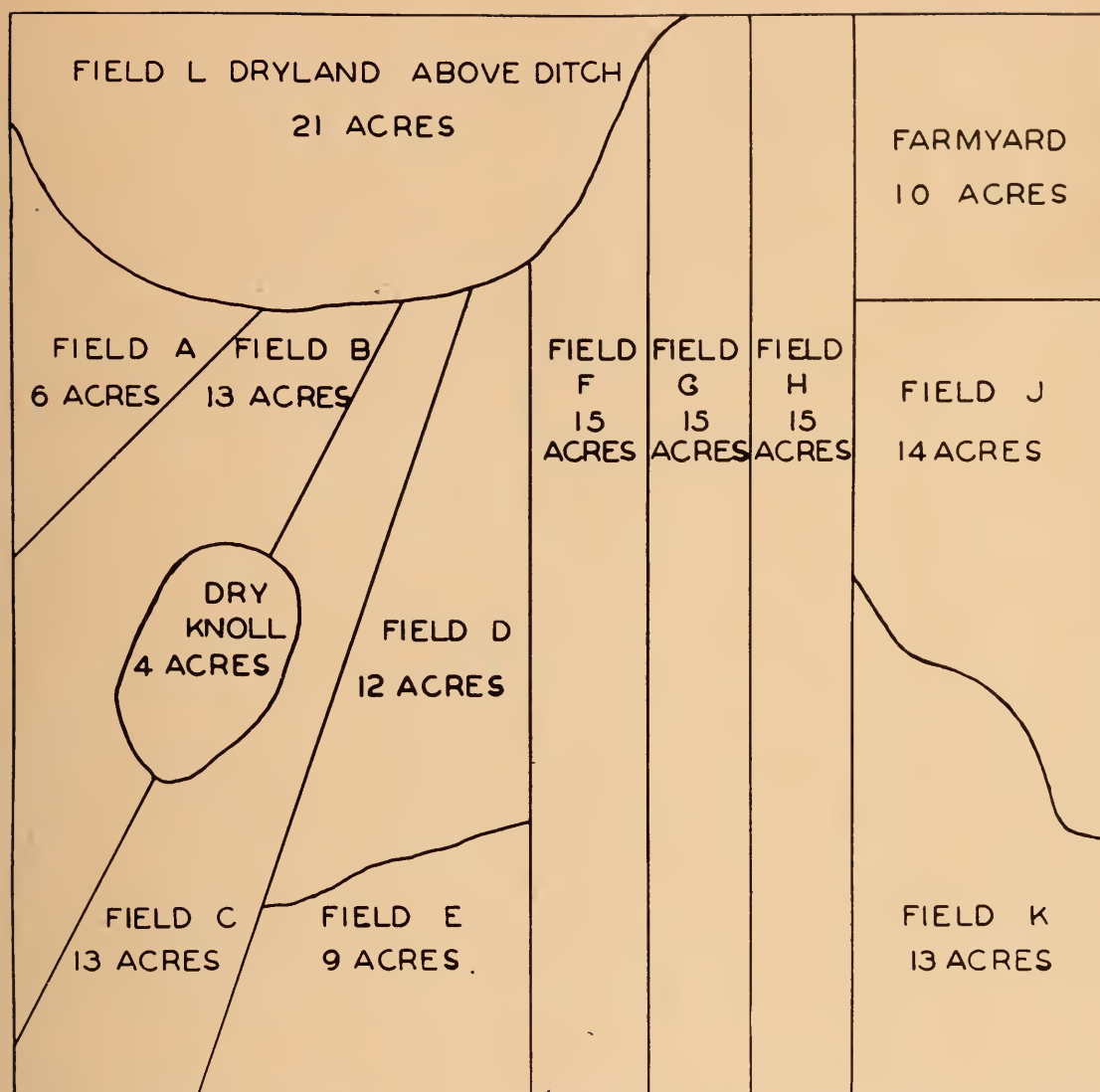


Fig. 13.—Layout of an irrigated farm of irregular topography into fields of approximately equal size to which a permanent crop rotation can be applied.

to fit into the indicated fields in Fig. 13. The rotation is as follows: alfalfa, alfalfa, alfalfa, peas, sugar beets, sugar beets, barley, barley, wheat and alfalfa. Such a rotation would require nine fields or cropping units and these are obtained by dividing the uniform portion of the farm into three fields of 15 acres each and by considering Field A (6 acres) and Field E (9 acres) as one unit. This gives nine units varying in size from 12 to 15 acres to which the 9-year rotation can be applied. The lack of uniformity in size of the different fields will make a slight variation in the acreage of any one crop from year to year but this is not of great magnitude. The acreages of the various crops as they would occur over a 9-year period are set forth in Table 13, and the perpetual cropping plan is

TABLE 13—ANNUAL ACREAGES OF VARIOUS CROPS GROWN IN A NINE-YEAR ROTATION ON FIELDS OF VARYING ACREAGE DEPICTED IN FIG. 13

—	Alfalfa	Peas	Beets	Barley	Wheat	Total
1951	41	12	30	29	13	125
1952	41	13	27	30	14	125
1953	42	13	25	30	15	125
1954	42	15	26	27	15	125
1955	44	13	28	25	15	125
1956	45	14	28	26	12	125
1957	42	15	27	28	13	125
1958	40	15	29	28	13	125
1959	38	15	30	27	15	125

TABLE 14—PERPETUAL CROPPING PLAN OF 10 IRREGULAR FIELDS SHOWN IN FIG. 13 SUPPORTING
A 9-YEAR IRRIGATED CROP ROTATION

Field Acreage	A 6	B 13	C 13	D 12	E 9	F 15	G 15	H 15	J 14	K 13
1951	Alfalfa	Alfalfa	Alfalfa	Peas	Alfalfa	Beets	Beets	Barley	Barley	Wheat and Alfalfa
1952	Alfalfa	Alfalfa	Peas	Beets	Alfalfa	Beets	Barley	Barley	Wheat and Alfalfa	Alfalfa
1953	Alfalfa	Peas	Beets	Beets	Alfalfa	Barley	Barley	Wheat and Alfalfa	Alfalfa	Alfalfa
1954	Peas	Beets	Beets	Barley	Peas	Barley	Wheat and Alfalfa	Alfalfa	Alfalfa	Peas
1955	Beets	Beets	Barley	Barley	Beets	Wheat and Alfalfa	Alfalfa	Alfalfa	Peas	Beets
1956	Beets	Barley	Barley	Wheat	Beets	Alfalfa	Alfalfa	Alfalfa	Beets	Beets
1957	Barley	Barley	Wheat and Alfalfa	Alfalfa	Barley	Alfalfa	Alfalfa	Peas	Beets	Beets
1958	Barley	Wheat and Alfalfa	Alfalfa	Alfalfa	Barley	Alfalfa	Peas	Beets	Beets	Barley
1959	Wheat and Alfalfa	Alfalfa	Alfalfa	Alfalfa	Wheat and Alfalfa	Peas	Beets	Beets	Barley	Barley

shown in Table 14. Such a scheme would utilize the 125 acres of irrigable land while the 21 acres of dry land which is shown as being too high to be irrigated might be alternately cropped to wheat and summerfallowed; or it may be handled otherwise depending upon moisture conditions. The 4-acre dry knoll might be seeded to crested wheat grass which would protect it from erosion and produce a crop of hay or seed in the favourable years.

Many other cropping arrangements could be given but these illustrations indicate that it is possible to select a suitable cropping plan for almost any farming enterprise. Furthermore, with care it will be possible to arrange a desirable and profitable sequence of crops in which, each spring, the farmer will find he has fields prepared for the successful production of the crops of his choice. Over the years his planned and stable production will leave him with a steadier income than his "opportunist" neighbours who plan their "rotation" each spring and frequently find that their fields are not fitly prepared for their choice of crops.

Many factors such as available markets, land topography, scarcity of labour, supply of irrigation water, and soil type have a decided influence on the choice of an irrigated crop rotation. Seldom is any one rotation specifically adapted to more than a few thousand acres.

In one section of southern Alberta a 3-year rotation of wheat and sweet clover, sweet clover summerfallow, sugar beets, is very common. This is sometimes extended to a 4-year rotation by growing two consecutive crops of wheat instead of a single crop. The practice of ploughing down the second-year growth of sweet clover as a green manure crop and conducting a summerfallow for the remainder of the year provides excellent preparation for the succeeding crop of sugar beets. In addition a very high yield of wheat generally is obtained following the sugar beets. Thus two high yielding crops compensate for the one-third of the farm that annually does not produce a crop. Such a rotation, without the addition of barnyard manure, cannot be considered permanent but probably would produce satisfactory crops for many years if commercial fertilizers were used.

Some farmers on small acreages have successfully used a 2-year rotation of canning peas and sugar beets for a number of years. Yields have been maintained by manuring half the farm each year; but much of the necessary feed for livestock fattening must be purchased or manure must be secured from sources off the farm. Even though it may be possible to secure profitable yields temporarily in such a short rotation, this practice cannot be recommended. It is well known that insect pests and plant diseases may build up rapidly when one crop occurs too frequently on the same land and there are many other attendant difficulties.

THE PLACE OF LIVESTOCK ON THE IRRIGATED FARM

A farmer who continually sells all the crops he produces for cash is steadily depleting his reserves and sooner or later will find that his fertility bank account has been overdrawn. Three tons of alfalfa hay, which may be produced readily on one acre, contain 140 pounds of nitrogen, 35 pounds of phosphoric acid (P_2O_5) and 135 pounds of potash, having a total value of approximately \$35 if purchased in the form of commercial fertilizers. However, when farm products are fed to livestock nearly three-quarters of the fertilizing constituents are recovered in the manure and thus can be returned to the land. Selling livestock products is not nearly so exhaustive of fertility as is the selling of field crops; a carload of two-year-old fat steers does not contain as much phosphorus as 400 bushels of wheat.

The irrigation farmer who purposes to operate a permanent enterprise should include livestock in his program. The fertility of his farm cannot be maintained economically without the addition of manure. All types of livestock

production on irrigated farms have at least two factors in common—each serves as a means of converting “raw” products such as field crops into the “manufactured” articles of meat, milk, eggs, or wool and each leaves manure as a valuable by-product.

Manure

A ton of average farm manure contains approximately 10 pounds of nitrogen, 5 pounds of phosphoric acid and 10 pounds of potash. To buy these as commercial fertilizer at 1951 prices would cost about \$3. However, manure increases yields greatly in excess of what would be expected on the basis of its content of the three common fertilizer elements. In addition to providing plant food constituents manure improves the structure of soils; it increases the water-holding capacity; it stimulates and increases the micro-organic activity; it lightens a heavy soil and adds binding material to a light soil, thus reducing the susceptibility to water erosion; it adds vitamins and hormones as well as many trace elements such as boron and iron, which although required only in minute amounts are nevertheless indispensable to plant growth.

Importance of liquid manure

About half the nitrogen, almost all the phosphorus, and approximately two-fifths of the potash are found in the solid portion of the manure. However, the plant food materials in the liquid manure or urine are much more readily available. Too often, much valuable fertilizer material is lost because care is not taken to provide enough bedding or litter to take up the liquid portion. Oat straw will take up and hold about $2\frac{1}{2}$ times its weight of water; wheat straw is somewhat less absorptive.

Amount of bedding

Cereal straw used as bedding makes a valuable addition of organic matter to the animal excreta. Fresh manure, particularly the urine, adds nitrogen to the straw and under suitable conditions the whole mass becomes “digested” by micro-organisms into a well-balanced soil ameliorant. Too much bedding results in a “strawy” manure which is not readily incorporated into the soil whereas too little bedding results in a loss of nutrients in the run-off of the liquids.

The weight of bedding should be equal to about one-fourth the dry weight of the feed. This means about 8 pounds per day per head for cattle; or for 100 steers, $2\frac{1}{2}$ or 3 tons of straw per week would be required. A good crop of irrigated wheat produces about $1\frac{1}{4}$ tons of straw per acre. The amount of straw from an acre of oats is a little higher and that from an acre of barley a little less.

Feeder cattle on full rations in a well-bedded feed lot will produce manure equal to about twice the weight of the feed eaten. One hundred steers on feed for five months should leave over 300 tons of high quality manure in the corral. Feedlot lambs produce less manure per 1,000 pounds of body weight than cattle but the manure is drier and will provide considerably more fertilizer value per ton.

Care and preservation

It has been pointed out that more than half the fertilizing elements of ordinary farm feeds remain in the manure after the feeds have passed through livestock. However, many of these elements are unstable and care must be exercised to prevent their loss before they can be applied to the land. Ideally it would be well to have both the solid and liquid portions of the manure incorporated into the soil immediately after they are produced. Such a practice would minimize losses of fertilizer elements but of course is highly impractical. However, a good deal can be done to preserve the value of the manure until it can be spread conveniently on the farm land.

Gutters or feedlot floors should be sufficiently tight or impervious to hold the liquid manure until it can be absorbed by the bedding. Furthermore no subsequent leaching should be allowed, as might occur following a rainstorm in an open feedlot. The manure mass should be kept moist and compact in order to exclude air and to keep the temperature low.

Fortunately, the common practice of winter finishing of livestock in open corrals as is done in the irrigated areas of Alberta is also a rather good method of conserving the manure. If the animals are kept well bedded so that the lots are reasonably dry the solid excreta and urine become readily mixed with the straw, and as the whole area of the feedlot is being continually trampled the manure mass is kept firm. The limited amount of rain or snow assists in maintaining the proper degree of moisture and on level ground there is no need to allow any run-off.

At the Experimental Station, Lethbridge, the manure from the dairy and horse barns is preserved in large, compact piles for at least a year before it is



Fig. 14.—Two thousand lambs have left 500 tons of manure in this corral. This manure is worth several thousand dollars on the basis of increased yields which will result when it is applied to irrigated land.

applied to the land. Being high in moisture when it is put into the pile, it packs well and a proper heating ensues which brings about a digestion of the bedding, kills some weed seeds, and results in a homogeneous mass of manure high in nutrients and moisture. The piles are somewhat hollowed on top so that rain and snow drain into the pile rather than off it. The limited precipitation in the Lethbridge area keeps the manure pile moist but seldom causes significant leaching. In the summer the surface dries to a depth of a few inches and provides good insulation so that the interior of the pile remains cool, hence there is little loss of nutrients from undue heating and volatilization. Chemical analyses of manure preserved in this manner indicate that it contains an average of 12 lb. of nitrogen and 9 lb. of phosphoric acid per ton as it comes from the pile after storage. The moisture content averages 70 per cent.

Application of manure

Methods.—Modern tractor-drawn manure spreaders operated by the power take-off are very efficient in the distribution of manure. These mechanical spreaders do a much more uniform job of spreading than is possible by hand methods. Tractor-mounted manure loaders also have added greatly to the convenience and speed with which manure can be removed from the pile or corral and spread on the field. One man using a manure loader and a standard 3-yard tractor-drawn spreader can regularly apply 50 tons of manure per day. Manure that is dropped by animals on pasture fields should be scattered by harrowing.

Rates.—On irrigated farms in Alberta the manure application usually varies from 8 to 20 tons per acre. Light dressings make a higher return in crop yields per ton of manure than do heavy applications. With 100 tons of manure avail-



Fig. 15.—Mechanical loaders and large manure spreaders have speeded up the job of putting out manure.

able generally it would be better practice to apply this to 10 acres at 10 tons per acre rather than to 5 acres at double this rate. When manure is plentiful it can be applied very heavily to some crops without ill effect.

There is usually a shortage of manure in intensively farmed irrigated areas. Most farmers apply all that they have or can procure readily, and hope that it will be sufficient. In general, the application of 2 or 3 tons of manure per acre per year is considered to be good practice. This could be accomplished by manuring one-quarter of the farm each year at the rate of 10 tons per acre or one-fifth of the farm at 12 to 14 tons per acre. It should be emphasized that this rate of application would not maintain the farm fertility but would be a practical rate and when used in conjunction with legumes, green manures, commercial fertilizers, and intelligent cropping practices, should result in farm lands of continued high productive capacity.

Time to Apply.—Much manure is spread on land in the early spring before cultural operations begin since both land and labour usually are available at

this time. If this manure is ploughed under as soon as possible and the subsequently seeded crop is well provided with moisture good results usually follow, particularly with well-rotted manure. Difficulty is sometimes encountered when strawy manure is ploughed under in the spring since the organisms which decay this material compete with the growing crop for both nitrogen and moisture and frequently there results a temporary shortage of both materials for the young crop plants.

In the relatively short growing season of these northern latitudes it is highly advantageous to apply the manure during the late summer. Frequently some land is available to receive manure at this time; most commonly this is summer-fallow or land from which a crop of canning peas or an early crop of cereals has been harvested. In a rotation where sugar beets follow canning peas it is ideal to apply the manure to the pea stubble in August and to follow the manure spreader immediately with the plough.

Manure is often spread on land in winter but this results in a considerable loss of nitrogen to the air and hence is a wasteful practice. Manure may be spread on pastures any time during the grazing season but preferably in the spring so that spring rains may wash the nutrients into the root zones. While there appears to be no ideal time for manure application on field crops best results generally are obtained if at least a few weeks elapse between the time of application and seeding. Except on pasture and hay crops the manure should be ploughed under as soon as it is spread.

Residual effect of manure

In an 8-year rotation at the Lethbridge Station 30 tons of manure per acre were applied to a series of plots in the fall of 1943 and the resulting yields on these plots compared with unmanured plots are shown in Table 15.

TABLE 15—AVERAGE YIELDS PER ACRE OF VARIOUS CROPS OVER A 7-YEAR PERIOD AFTER AN APPLICATION OF 30 TONS OF MANURE COMPARED WITH AVERAGE YIELDS FROM SIMILAR PLOTS RECEIVING NO MANURE

Year	1944	1945	1946	1947	1948	1949	1950
Crop	Beets (tons)	Beets (tons)	Wheat (bu.)	Wheat (bu.)	Alfalfa (tons)	Alfalfa (tons)	Alfalfa (tons)
Manure applied in fall of 1943:							
Thirty tons.....	24.57	19.88	56.8	50.7	4.50	4.55	4.83
None.....	15.70	16.00	49.6	43.1	3.10	3.10	1.86

These results show that heavy applications of manure have a residual effect evidenced in increased yields for at least 7 years. Lighter rates have a correspondingly shorter residual benefit but there are ample data to prove that a 10-ton application results in increased yields four years after it is applied.

Crops that respond to manure

Generally manure is applied to the most valuable crop in the rotation unless there is some specific reason for withholding it. Examples of crops that do not respond favourably immediately after heavy applications of manure are: potatoes, in which high organic matter is conducive to scabiness; and legume seed crops, because the high nitrogen of the manure encourages prolific vegetative growth rather than seed production. Root crops such as sugar beets and vegetables respond well to manure, often showing increases of 50 per cent in yield from a moderate application. Manure greatly increases the yield of potatoes but it is best to apply it the previous season. The yield of canning corn is also greatly increased by manure. With canning peas more careful fertilization is necessary to prevent rank vine growth with limited seed pods. Light manure applications together with phosphorus fertilizer have proved effective.

In mixed plantings for hay and pasture the grasses are stimulated more than the legumes. Legumes need abundant phosphorus and this is most economically supplied by commercial fertilizers. If alfalfa or other legumes are fertilized heavily with manure they will fix less atmospheric nitrogen. However, if the manure is available, increases in yield can be expected from applications to alfalfa.

With the cereal grains care is required in applying manure. Even moderate applications made directly to the crop may cause excessive growth of weak straw which will lodge readily. Best results are usually obtained by applying the manure to other crops in the rotation and leaving the cereals to benefit from the residual effect.

Reinforcement of manure

Since barnyard manure is an unbalanced fertilizer, containing a much larger proportion of nitrogen than phosphorus it is not uncommon to attempt to improve the phosphorus content of manure by adding phosphate fertilizer to it. This may be done by spreading it in stable gutters, by scattering it over the feedlot area or by adding it to each spreader load of manure as it goes to the field. For illustration let it be assumed that manure is to be spread at the rate of 10 tons per acre and it is desired to apply 100 lb. of 11-48-0 fertilizer per acre. In the dairy barn about one-quarter pound of this fertilizer per animal per day should be scattered over the manure in the gutters; in a feedlot of 100 steers 25 pounds of 11-48-0 should be distributed over the whole feedlot area daily. There are many advantages to adding phosphorus to manure by the above methods. These benefits may be enumerated as follows: (1) The addition of commercial fertilizer improves the balance of the manure. (2) There is less loss of nitrogen from reinforced manure. (3) The phosphorus is maintained in a more readily available form and there is less fixation than when the fertilizer is added directly to the soil. (4) There is no danger to germinating seedlings from fertilizer burning.

Value of manure

From a farmer's point of view a ton of manure is worth what it will net him in increased profits from larger yields, less the cost of application. Several experiments have been conducted at the Lethbridge Station to determine the value of barnyard manure in irrigated crop rotations. Tables 16 and 17 indicate the increased yields and money values resulting from manure applications.

TABLE 16—THE VALUE OF MANURE ON THE BASIS OF INCREASED YIELDS IN AN 8-YEAR IRRIGATED CROP ROTATION AT THE EXPERIMENTAL STATION, LETHBRIDGE

Crops in the Rotation	Average Yields ¹ per Acre, 1941-1950			Value of Increase (1950 Prices)
	With Manure ²	Without Manure	Increase Due to Manure	
First year—Sugar beets.....	21.54	12.80	8.74	\$133.28
Second year—Sugar beets.....	20.15	14.03	6.12	93.33
Third year—Wheat.....	54.0	49.2	4.8	7.20
Fourth year—Wheat seeded down to Alfalfa..	48.3	43.1	5.2	7.80
Fifth year—Alfalfa.....	3.63	2.40	1.23	27.06
Sixth year—Alfalfa.....	3.71	1.85	1.86	40.92
Seventh year—Alfalfa.....	3.23	1.60	1.63	35.86
Eighth year—Wheat.....	41.3	31.8	9.5	14.25
Thirty tons manure gave increased yields valued on 1950 prices at.....				\$359.70

Value of manure per ton—\$11.99

¹ Yields of sugar beets and hay in tons and of grain in bushels.

² Thirty tons of manure per acre were applied once every eight years in the fall previous to the first crop of sugar beets.

TABLE 17—THE VALUE OF MANURE ON THE BASIS OF INCREASED YIELDS IN A 4-YEAR IRRIGATED CROP ROTATION AT THE EXPERIMENTAL STATION, LETHBRIDGE

Crops in the Rotation	Average Yields ¹ per Acre, 1941-1950			Value of Increase (1950 Prices)
	With Manure ²	Without Manure	Increase Due to Manure	
First year—Sugar beets.....	20·29	13·15	7·14	\$108·88
Second year—Sugar beets.....	18·67	13·98	4·69	71·52
Third year—Wheat.....	49·6	40·8	8·8	13·20
Fourth year—Barley.....	66·8	51·9	14·9	14·90
Twenty tons manure produced increased yields to the value of..... (1950 prices)				\$208·50

Value of manure per ton—\$10·42

¹ Yields of sugar beets in tons and of grain in bushels.

² Twenty tons of manure per acre were applied once every four years in the fall previous to the first crop of sugar beets.

COMMERCIAL FERTILIZERS

More than a dozen chemical elements now are known to be indispensable to plant growth but the fertilizer trade is concerned primarily with only three of these: nitrogen, phosphorus, and potassium. These are commonly referred to as the fertilizer elements and are most often the limiting factors in crop production. In most countries the statutes require that a guaranteed analysis of the fertilizer elements be marked on every bag of fertilizer that is sold. In Canada and the United States this always takes the form of three percentage figures separated by dashes as, 6-30-15, which means that this fertilizer contains 6 pounds of nitrogen (N), 30 pounds of phosphate (P_2O_5) and 15 pounds of potash (K_2O) per 100 pounds of fertilizer. The elements are always listed in the same order, i.e., nitrogen, phosphorus, potassium. Since the percentages of these fertilizing elements are the criteria by which the worth of the various commercial fertilizer brands can be judged, it has become common to refer to many types of fertilizer by the three percentages which represent the guaranteed analysis; e.g. the common fertilizer applied with sugar beets at time of seeding is 11-48-0, while the nitrogenous fertilizer used later in the season as a side dressing is usually 21-0-0, or 33-0-0. It will be noted that these two latter formulations contain no phosphorus and no potassium.

In purchasing commercial fertilizers a farmer should be guided by the guaranteed analysis. He should figure out how much he is paying per pound of nitrogen, phosphorus, and potassium, and buy them in the cheapest form. Generally speaking a 10-20-10 fertilizer is worth twice as much as a 5-10-5 formulation. There are additional factors to consider in purchasing fertilizers; these include chemical balance, availability of nutrients, concentration of salts, type of soil and crop, and many others. Farmers are advised to consult their local district agriculturist for information on specific problems.

Commercial fertilizers are only supplementary

Commercial fertilizers provide necessary plant food but in no way can they compensate for poor husbandry. Such fertilizers will do little to improve an alkali soil, or a soil in poor tilth. Commercial fertilizers cannot replace manure, nor indeed can manure economically replace commercial fertilizers where a specific deficiency exists. On intensively-cropped irrigated lands, farmers will find it profitable to apply all available manure to their crop lands. When this has been done, the fertilizer elements removed by the crops will likely outweigh the amounts added in the manure. Usually the cheapest way to make up the shortage is by applying commercial fertilizer.

Distinct need for phosphate fertilizers on irrigated prairie soils

The need for phosphate fertilizers on the irrigated soils of Alberta has been well established by experiment and demonstration. An application of 100 lb. per acre of ammonium phosphate, 11-48-0, often has brought about increases of 25 per cent in the yield of sugar beets or alfalfa. Phosphate fertilizers are not leached out of the soil and when this type of fertilizer is applied even in excess of the needs of the current crop, the phosphorus remains in the soil and is available to subsequent crops.

Potash supply in prairie soils

The potassium content of fertilizer is usually expressed in the form of potassium oxide (K_2O) and is referred to as potash. Prairie soils are high in potash. Additions of potash fertilizers have never brought about increased yields in the numerous tests that have been conducted on irrigated land in Alberta. Table 18 indicates that an average 160-acre farm has an annual net loss of about 6,000 lb. of potash. It is obvious that it is only a matter of time until this element will be a limiting factor in crop production. However, it would not be sound economically to recommend that potash fertilizers be applied now to replace the current losses.

SOIL DRIFTING CONTROL ON IRRIGATED LAND

As mentioned in an earlier section, much of the present irrigated area lies in the direct path of the Chinook winds. These winds, which may reach high velocity any time during the year but particularly in the winter and spring, are capable of causing serious losses of topsoil from unprotected fields. The dry-land farmer in the Chinook belt has learned how to hold his soil by practising strip cropping and trash-cover farming. However, his neighbour on irrigated land cannot always make use of these effective control methods.

During almost every winter and spring considerable soil drifting has occurred from fields that have grown sugar beets, potatoes, or vegetables during the preceding season. These crops are harvested late in the fall and frequently the fields go into the winter without any tillage treatment. The cultivation mulch of the summer thus provides a soil structure highly susceptible to wind erosion. In addition, the practice of pasturing off beet tops with cattle or sheep further predisposes beet land to soil drifting.

Prevention of winter drifting on exposed crop land

Wherever possible the different types of bare crop land, discussed above, should be ploughed with a mouldboard plough before winter sets in. Generally this treatment will "windproof" the fields until seeding time the following spring. Frequently farmers are reluctant to plough their beet land as they wish to pasture off the beet tops rather than turn them under. Under these conditions, beet fields that are likely to blow should be ridged up with a lister cultivator between the windrows of beet tops. An ordinary duckfoot cultivator usually will bring up enough clods to roughen the surface and stabilize the finer material. A 12-foot cultivator with the regular duckfeet removed and 4 lister shovels mounted 3 feet apart makes a very satisfactory lister for wind erosion control. Such an implement will fit readily between the windrows of beet tops from eight rows of beets and will provide cheap protection against loss of valuable topsoil.

Prevention of drifting on partial summerfallows

In the course of preparation of fields for the production of specialty crops, irrigation farmers often conduct a partial summerfallow after canning peas have been harvested or sweet clover has been ploughed under as a green manure crop. This fallow land usually is irrigated and ploughed and well worked down and

levelled during the summer in readiness for seeding small seeded crops, such as sugar beets, the following year. No fault is to be found with this practice except that these well prepared fields may be subject to severe soil drifting. However, drifting can be prevented easily on such fields by late fall ploughing. In addition to providing insurance against soil erosion it has been observed repeatedly that summerfallow fields, which have been ploughed twice (once in summer and once in autumn), produce higher yields than comparable fields which have been ploughed only once.

Emergency control methods

In the control of soil drifting as in many other pursuits an ounce of prevention is worth a pound of cure. However, if prevention has been neglected or has failed then a cure must be applied. As soon as soil begins to move off an area steps should be taken to stabilize the field. Any implement that will roughen the surface and bring up small clods, thus allowing the finer soil particles to sift down below the lumpy surface, will temporarily stop soil drifting. Cultivators and spring-tooth harrows are among the best implements. Even a good harrowing with a spike-tooth harrow often will hold a field through one severe wind-storm or until more lasting tillage can be applied.

Some of the most severe soil drifting occurs in the middle of winter. The Chinook winds blow the frozen fields bare of snow and as the winds continue, the



Fig. 16.—A very effective "frozen soil lister" can be fashioned from a oneway disk. This implement will stabilize a soil which begins blowing while the soil is still frozen.

soil thaws out to a depth of one-quarter inch or even less and this soil begins to move off the field as fast as it is thawed out. At the Experimental Station, Lethbridge, methods have been devised to combat this insidious form of soil erosion. It has been found that a "frozen soil lister" can be fashioned readily by removing all but every fourth pan from a one-way disk and making necessary

adjustments of the hitch. Since this implement is relatively heavy it will penetrate the frozen ground and leave small ridges of frozen material that serve to trap the fine particles which are being picked up by the wind.

Another emergency control method is to scatter a light coating of manure or wet straw from an old stack bottom over the drifting field. If this material is wet it will be sufficiently heavy to resist being blown away until it becomes well anchored by the small dunes of soil which will soon build up around it. Low quality hay or straw also has been used successfully although it is necessary to incorporate this material into the soil by disking or it may be blown away before it can accomplish its purpose.

Cover crops

The use of cover crops to prevent soil drifting has become standard practice in the dry-land wheat region adjacent to the foothills in Alberta. Usually a light seeding of oats is made in July on the summerfallow and the resulting growth has been used very profitably as a pasture for beef cattle during the fall and early winter.

Cover crops of oats have been seeded also on irrigated land following canning peas or following the summer ploughing down of green manure crops such as sweet clover. In the foothills area a six weeks pasture period is usual but this has been lengthened in the irrigated section of the Chinook belt. Feeder cattle make excellent gains on cover crop pasture and carrying capacity is at least one head per acre for the six weeks pasture season. This makes the cover crop a profitable financial undertaking as well as an excellent wind erosion control.

The disadvantages of cover cropping on irrigated land are the attendant difficulties of preparing a suitable seed-bed the following spring for small seeded crops such as sugar beets. In a dry spring season the limited moisture in the upper 2 or 3 inches of soil may not be sufficient to ensure satisfactory germination. Of course the field may be irrigated in the spring if seeding can be delayed safely until about May 15. With sprinkler irrigation equipment the crop may be planted in dry soil and a light sprinkling applied to germinate the seed if timely rains do not occur.

Control of drifting immediately after seeding

In order to ensure satisfactory emergence of small seeded crops it is necessary that the seed-beds be fine, firm, and friable. This type of preparation predisposes the land to soil drifting. Many newly seeded fields of sugar beets have had the seed as well as the finely-prepared mulch completely blown off the farm by one severe windstorm. Such catastrophes can be lessened in frequency by making a furrow between the rows of beets at time of planting. These furrows frequently are made so that they will be available if it should become necessary to irrigate the beets to provide sufficient moisture for germination. On light soils which are very susceptible to blowing these furrows should be made as deeply as feasible and in every row rather than in every other row as is usually done for irrigation purposes. This recommendation applies also to seedings of corn and beans although these two crops can be seeded more deeply and do not require a seed-bed so fine as do sugar beets. In some light sandy soil areas it has been found advisable to spring plough the land before seeding beets in order to have some small "cobble" aggregates at the soil surface to add stability to the seed-bed.

Little difficulty is experienced with soil drifting on potato seed-beds as the common method of ridge planting usually provides adequate protection. Fields seeded to grain crops generally are quite well ridged by the press wheels of the seeder. If drifting begins it may be stopped by a spike-tooth harrowing at right angles to the direction of the wind.

WEED CONTROL

Weed control is a major problem on irrigated farms. In addition to the usual sources of infestation the irrigation water serves as a carrier for weed seeds of all kinds and the ample supply of moisture results in rank growth and abundant seed production.

Control methods on irrigated land, as in other types of farming, are divided into cultural and chemical methods. On a well organized irrigated farm, growing a percentage of row crops and perennial hay crops, weeds need not be a serious menace. No weeds should be allowed to go to seed in any intertilled crop and mowing generally prevents seed formation in perennial hay crops.

Annual weeds

Control by Culture.—Since annual weeds are re-established from year to year by seeds the obvious control is the prevention of seed formation. This can be accomplished by clean cultivation as in summerfallowing or by inter-row tillage and hoeing on row crops. Most soils contain an abundance of weed seeds and, during any season in which complete eradication of weeds is being attempted from a field, conditions should be made as favourable as possible for weed-seed germination. Thus the weeds must be “grown out” of the land. Summer-fallow should be irrigated to maintain suitable moisture conditions and after one crop of weeds has germinated and been killed the land should be tilled to turn up another set of seeds for sprouting and eradication.

Control by Chemicals.—Great advances have been made in the development of selective herbicides during the past decade. It is now common practice to control many annual weeds in cereal grain crops by chemical applications without damaging the growing crop. When properly applied these selective herbicides have given good results and their use is to be recommended. Information concerning recommended formulations may be had from local agricultural extension officers.

Perennial weeds

Many parcels of irrigated land have been reduced greatly in value by infestations of persistent perennial weeds. Weeds such as field bindweed, hoary cress, leafy spurge, and Russian knapweed are able to resist the usual methods of eradication, and frequently offer serious competition to growing crops. Farmers should be familiar with these weeds in order to recognize and eliminate them while infestations are limited.

Control by Culture.—Most persistent perennials have underground root-stocks in which food material is stored. The above-ground growth may be destroyed, but as long as the necessary stored food is available these root-stocks continue to send up new shoots. When the new green growth has been above ground for 4 or 5 days, storage of manufactured food material in the roots begins again. Thus the objective of control by culture must be sufficiently frequent cultivation to deplete the root reserves and prevent their replenishment. In an experiment conducted by the Experimental Station, Lethbridge, on the control of field bindweed it was necessary to cultivate the land nine times during the first season of summerfallow, seven times during the second season and four times during the third season, to bring about complete eradication. The infestation was greatly reduced by the third year, and perhaps the few plants that remained could have been eliminated by careful hoeing in a row crop.

Control by Chemicals.—Small patches of persistent perennials can be controlled by sterilizing the soil with chemicals such as sodium chlorate. These eliminate all growing plants on the treated area for a number of years. Another

chemical, carbon disulphide, sterilizes the soil for only a few weeks, and is effective in destroying weeds but is not widely used because of the high cost of material and application.

The newer hormone-type sprays such as 2,4-D have been helpful but rarely have they eliminated these persistent perennials. However, more recent developments continue to be promising. A combination of cropping practices and chemical treatment has been effective in controlling these weeds in some cases.

PLANNING FOR PERMANENCE AND BALANCE IN THE FARMING ENTERPRISE

Like all business undertakings, the farming enterprise must have a long-term point of view if it is to be successful. This is especially true on an irrigated farm where the initial capital outlay is high. Frequently it requires many years of efficient work and astute saving to retire the original debt incurred on the purchase of the land and equipment and this usually demands annual payments which, in turn, can only be made if consistently good yields are obtained.

Preservation of fertility

As discussed earlier, satisfactory yields result from careful attention to variety selection, fertility, husbandry, crop sequence, and many other factors. The preservation of fertility may be said to be the keystone of successful farming because without it, no amount of careful adherence to other details will produce high yields. A farmer should consider the natural fertility elements of his soil in the same class as his cash account in the bank; both are there to be used but if withdrawals are made in excess of deposits both will become overdrawn. Few farmers realize that a 12-ton crop of beets (not including tops) on 30 acres removes from the farm as much nitrogen as contained in 60 bags of sulphate of ammonia (20-0-0), as much phosphorus as contained in 13 bags of ammonium phosphate (11-48-0), and as much potash as contained in 40 bags of potassium chloride (0-0-60).

Balance sheet of farm fertility

Therefore, wise farmers try to keep their fertility bank account in creditable standing by good husbandry and the use of barnyard and green manures as well as commercial fertilizers. It is quite possible and, in fact, highly desirable, to figure out an annual fertility balance sheet for a farm. This has been done for the farm depicted in Table 10; the results are shown in Table 18. This balance sheet uses the average yields of crops in the irrigated area of southern Alberta and the acreages set out for each crop in Table 10. Since permanency in irrigation farming requires manure the wise farmer will feed most of his crop on the farm. In Table 18 the only field crops which are indicated as being sold off the farm irrevocably are green peas for canning, sweet corn ears for canning, and the refined sugar from the sugar beets (the beet pulp is returned to the farm for feeding).

Table 18 indicates the amount of total digestible nutrients and fertilizer elements in each crop grown on the farm and also the number of lambs this amount of feed would fatten together with their production of manure and its content of nitrogen, phosphorus, and potassium. Approximately 50 tons of cereal straw would be produced on this farm, sufficient to provide adequate bedding for the lambs; this would be converted to manure making a total of 323 tons ($273 + 50$) to be applied to the 150 acres of crop land each year. This would make possible an application of 11 tons per acre to the 30 acres of land being prepared for sugar beets. As a general rule, an average of two tons of manure per acre per year is regarded as a minimum amount under irrigation farming.

TABLE 18—FERTILITY BALANCE SHEET ON 160-ACRE IRRIGATED FARM DEPICTED IN TABLE 10

Crop	Acreage	Average Yield	Total Production	Feeding Units	Fertilizer elements removed by crops		
					Nitrogen (N)	Phosphorus (P ₂ O ₅)	Potassium (K ₂ O)
		bu. or tons per acre	lb.	(t.d.n.), lb.	lb.	lb.	lb.
Sugar Beets.....	30	12.0	720,000	.....	1,188	612	2,412
Beet tops (dry matter).....			72,000	40,536	1,631	922	3,035
Dry pulp (4½% on beets).....			32,400	21,967	.....	.....	.....
Canning Peas.....	30	1.0	60,000	.....	.....	.....	.....
Pea Vine Hay.....		2.0	120,000	60,000	.....	170	163
Canning Corn.....	20	4.2	168,000	.....	504	446	2,250
Corn Stover Silage.....		4.0	160,000	22,240	592	156	648
Alfalfa.....	20	2.25	90,000	45,270	.....	149	578
Barley.....	30	42.0	60,000	47,598	1,134	454	1,688
Oats.....	10	54.0	18,360	13,137	351	466	302
Wheat.....	10	32.0	19,200	16,128	416	140	97
Totals.....				266,876	5,816	3,688	11,275
Nitrogen added by sweet clover green manure crop (20 acres × 40 lb.).....							
<i>Livestock Feeding Capacity</i>							
266,876 lb. of total digestible nutrients will feed 1,335 lambs for 100 days (200 lb. t.d.n. required to produce 25 lb. net gain in 100 days). Each lamb will produce 4 lb. fresh manure daily; a total of							
$\frac{4 \times 100 \times 1,335}{2,000} = 273 \text{ tons which contains.....}$							
Net loss of fertilizer elements.....							
800					4,434	1,720	5,223
.....					-582	-1,968	-6,052

The balance sheet indicates decided losses in all three fertilizer elements and these deficits should be made up by the addition of commercial fertilizer or by purchasing additional feed to fatten a greater number of livestock thus producing more manure.

Leguminous crops derive a large share of their needed nitrogen from the air and also leave some of this nitrogen in their roots in the soil when they are harvested. In Table 18 it has been assumed that the alfalfa and pea crops leave the soil without loss or gain in nitrogen. The sweet clover crop which is ploughed under as green manure early in its second year of growth has been estimated to add 40 pounds of nitrogen per acre. The final accounting shows a net loss of 582 lb. of nitrogen which could be supplied by the application of about 29 bags of sulphate of ammonia, of 53 bags of ammonium phosphate, 11-48-0. The nitrogen balance of a farm growing leguminous crops is difficult to appraise because the amount of fixation of air nitrogen by the legumes is dependent upon many factors and hence is highly variable. However, studies by the Experimental Station, Lethbridge, indicate that the nitrogen supply is being well maintained on farms where livestock feeding is an integral part of the farming operation. Fields of sugar beets on many widely scattered livestock farms have shown little response from side dressings of relatively high amounts of nitrogen fertilizers. On the other hand beets on the non-manured farms usually have responded to this additional nitrogen.

The indicated phosphorus (P_2O_5) deficit of 1,968 lb. in Table 18 could be supplied by the application of 4,100 lb. of ammonium phosphate, 11-48-0, to the farm. According to present farming practice in Alberta, irrigation farmers regularly apply 100 lb. of 11-48-0 per acre to their sugar beets, thus the farm under discussion normally would receive 3,000 lb. of this fertilizer on the beet crop, and a moderate annual application to the alfalfa field would keep the phosphorus of the farm in balance.

The soils of southern Alberta are well supplied with potash. In numerous experiments the addition of potash fertilizer has not resulted in increased yields. However, if a quarter section of irrigated land loses 6,052 lb. of potash per year, as indicated in Table 18 the time will come when additions of this element will be necessary.

A balanced labour program on the irrigated farm

Intensive irrigation farming has a high labour requirement. In one of the irrigation districts of Alberta where the greatest intensification of specialty crop production occurs there is an average resident population of ten people per quarter section of land. Besides his own family a farmer usually requires additional help from early spring to late autumn. If by planning a livestock feeding program for the winter months, he can offer his help year-round employment it will be much easier for him to secure labourers of a high quality.

Modern irrigation farming methods are highly mechanized. This fact at once accounts for a reduction in the number of labourers required and an increased skill in those who are hired. A mechanically-inclined hired man, supplied with a home repair shop, can be profitably employed at overhauling and repairing machinery during slack periods.

The irrigated farm usually provides summer and casual employment for the operator's family, and high school students often assist greatly during summer labour peaks, particularly at hoeing and in the garnering of canning crops.

The careful operator governs his choice of varieties and seeding dates so that all subsequent work with each crop can be done at the proper time. For instance, it is costly to delay irrigating sugar beets because of haying operations, and it is well to have grain threshing finished before the date for beet harvesting.

In this connection, the value of keeping a daily record of operations cannot be overemphasized. A few notes on a calendar hanging in the tractor shed are helpful. Many farmers use a daily journal and record weather data, business transactions, receipts and expenditures, as well as notes on daily work.

SUMMARY

1. The irrigated lands of southern Alberta are well established as a stable agricultural area. The climate is suitable for irrigation farming and a half century of experience indicates that a wide variety of profitable crops can be grown in abundance.
2. The major proportion of the irrigation development lies within the brown soil zone. The soils of this zone were developed under a short-grass vegetation and limited rainfall. These soils are of high native fertility and have responded well to irrigation. Few serious problems of management have arisen, but increased attention should be given to drainage.
3. Production practices are discussed for the most common crops grown under irrigation in Alberta. These include alfalfa, sugar beets, cereal grains, potatoes, canning crops, and irrigated pastures.
4. Crop rotation is an essential concomitant of irrigation farming. The rotation should be planned to include the maximum acreage of profitable crops that is compatible with soil conservation and available labour and equipment. Other factors to consider are the control of pests and weeds, use of shallow-rooted and deep-rooted crops as well as sod and inter-tilled crops. Crop rotation distributes risks, allows for more accurate forecasting of annual returns, and provides fuller utilization of available soil fertility. This bulletin describes several rotations for irrigated farms.
5. Livestock production is an integral part of irrigation farming. Barnyard manure is almost indispensable in the maintenance of soil fertility and structure.
6. Care is required to prevent the loss of fertilizing elements from manure during storage before it is applied to the land. Light applications usually produce a higher return in crop yields per ton of manure than do heavier dressings. There is a distinct residual benefit that lasts for several years after a manure application.
7. Commercial fertilizers are useful and economical supplements to good farm practice. The value of a fertilizer is determined mainly by its percentages of nitrogen, phosphorus, and potash, which are always printed on the bag.
8. The various methods of irrigating are discussed and the choice of a method is shown to depend on type of soil and crop, topography, availability of labour and capital, etc.
9. It is essential that weeds be controlled if maximum production is to be obtained on an irrigated farm. Crop rotation, careful cultural practices, and chemicals are all useful in weed control.
10. A fertility balance sheet for a 160-acre irrigated farm is included. The calculations show large annual losses of fertilizer elements even when most of the crops are fed on the farm and the manure returned to the land.
11. The bulletin stresses the necessity for careful planning of cropping practices, labour requirements, and fertility maintenance in order to provide stability and permanence to the irrigated farm enterprise.



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